TECHNICAL REPORT NO. 65-52

OPERATION OF THE WICHITA MOUNTAINS SEISMOLOGICAL OBSERVATORY

Semiannual Report No. 2, Project VT/4054

1 December 1964 through 31 May 1965

GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD

GARLAND, TEXAS

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THE GEOTECHNICAL CORPORATION
3401 Shiloh Road
Garland, Texas

8 June 1965

IDENTIFICATION

AFTAC Project No: VT/4054
Project Title: Operation of WMSO
ARPA Order No: 104
ARPA Code No: 8100
Contractor: The Geotechnical Corporation,
Garland, Texas
Date of Contract: 1 July 1964
Amount of Contract: $453,176
Contract No: AF 33(657)-13562
Contract Expiration Date: 31 October 1965
Program Manager: B. B. Leichliter, BR8-8102

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OPERATION OF THE WICHITA MOUNTAINS SEISMOLOGICAL OBSERVATORY

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1. INTRODUCTION

1.1 AUTHORITY

This is a report of the work done on Project VT/4054 from 1 December 1964 through 31 May 1965. This project includes the operation, evaluation, and improvement of the Wichita Mountains Seismological Observatory (WMSO) located on the Fort Sill Military Reservation in southern Oklahoma. It also includes special seismological investigations using data from WMSO and other seismological observatories. Authority for the operation of WMSO is contained in Contract AF 33(657)-13562, dated 1 July 1964. The statement of work for Project VT/4054 is included as appendix 1 to this report. The Air Force Technical Application Center (AFTAC) has technical supervision of the contract as a part of Project VELA-UNIFORM, which is under the overall direction of the Advanced Research Projects Agency (ARPA).

1.2 PURPOSE OF WMSO

The purpose of WMSO is threefold. First, the standard instrumentation of the observatory is maintained and continually evaluated and seismometric data are recorded, analyzed, and reported to the United States Coast and Geodetic Survey (USC&GS) daily. Second, WMSO is used as a field laboratory where new instruments and techniques are tested and evaluated to determine their value for use at an observatory. Third, the data recorded at WMSO are studied, separately and in conjunction with data from other observatories, in an effort to improve and refine interpretive techniques and to learn more about earthquake mechanisms and the mechanisms of propagation of seismic waves through the earth.

1.3 HISTORY OF WMSO

WMSO was designed, constructed, and equipped in 1960, under Phase I of Contract AF 33(600-41318, Project VT/036. The seismic instrumentation has characteristics recommended by the 1958 Geneva Conference of Experts to Study Methods of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests. The general parameters of the equipment recommended by the

1958 Geneva Conference of Experts are quoted in, and the standard instrumentation of WMSO is described in, Information Bulletin No. 2 of the Wichita Mountains Seismological Observatory published on 1 January 1963. The work done during Phase I of Contract 41318 is described in Geotech Technical Report No. 61-1 published on 10 January 1961. Phases II, III, and V and the extension of Phase V, Contract 41318, included the recording and evaluation of seismometric data at WMSO and modifications or additions to the standard instrumentation in an effort to improve the detection capabilities of the observatory. Phases II, III, and V and the extension of Phase V covered the period 1 October 1960 through November 1964 and are described in Geotech Technical Reports Nos. 61-2, 62-8, 63-54, and 64-118, respectively.

2. OPERATION OF WMSO

2.1 STANDARD SEISMOGRAPH OPERATING PROCEDURES

2.1.1 Seismograph Frequency Response

The operating parameters and tolerances for allowable deviations from these parameters are shown in table 1. These parameters are checked and reset, as necessary, when the frequency response check is made. The calibration norms and their respective tolerances for the frequency response checks are shown in table 2. The mean response characteristics of WMSO seismographs are shown in figure 1.

2.1.2 Motor Constants (G) for Short-Period Seismographs

In November 1964, just prior to this reporting period, the motor constants of the short-period seismographs were tested and adjusted. The values established at that time follow:

Instrument	G	Instrument	G
Z1	0.352	Z9	0.357
Z2	0.365	Z10	0.351
Z3	0.349	Z11	0.355
Z4	0.356	Z12	0.358

Table 1. Operating parameters and tolerances for the WMSO seismographs

Seismograph	Operating parameters and tolerances					Filter bandpass at 3 dB cutoff (sec)	Filter cutoff rate at SP side (dB/oct)
	T_s	λ_s	T_g	λ_g	σ^2		
SP vertical and horizontal Johnson-Matheson	1.25 ±2%	0.51 ±5%	0.33 ±5%	0.65 ±5%	0.03	0.1-100	12
UA SP vertical Benioff	1.0 ±5%	0.8	0.0625 ±5%	0.70	0.63	-	-
IB vertical Melton	1.6 ±5%	0.7 ±5%	0.2 ±5%	3.0 ±5%	0.02	0.1-100	12
IB horizontal Geotech	1.6 ±5%	0.7 ±5%	0.2 ±5%	3.0 ±5%	0.002	0.1-100	12
BB vertical Press-Ewing	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0 0002	0.05-100	12
BB vertical Geotech	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0.0002	0.05-100	12
BB horizontal Sprengnether	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0.0004	0.05-100	12
LP vertical and horizontal Geotech	20.0 ±5%	0.74 ±5%	110 ±10%	1.0 ±5%	0.1	{ LP_1 25-1000 { LP_2 20-1000	12 12[a]

Key to abbreviations

SP - Short-period
UA - Unamplified (earth-powered)
IB - Intermediate-band
BB - Broad-band
LP - Long-period
T_s - Free period of seismometer (seconds)
λ_s - Damping constant of seismometer
T_g - Free period of galvanometer (seconds)
λ_g - Damping constant of galvanometer
σ^2 - Coupling coefficient

[a]Uses a 6-second notch filter followed by a filter amplifier to reduce the response at low frequencies.

Table 2. Present calibration norms and tolerances for frequency responses of seismographs at WMSO

SP Johnson-Matheson vertical and horizontal

f (Hz)	T (secs)	R. M.	A. T. (± %)
0.2	5.0	0.0113	10
0.4	2.5	0.0950	7.5
0.8	1.25	0.685	5
1.0	1.0	1.0	-
1.5	0.67	1.52	5
2.0	0.5	1.90	5
3.0	0.33	2.12	7.5
4.0	0.25	1.87	12
6.0	0.167	1.15	20

BB vertical and horizontal

f (Hz)	T (secs)	R. M.	A. T. (±%)
0.04	25.0	0.104	20
0.06	16.7	0.350	20
0.08	12.5	0.775	15
0.1	10.0	0.950	10
0.2	5.0	1.00	5
0.4	2.5	1.00	5
0.8	1.25	1.00	-
1.6	0.625	1.00	5
3.2	0.312	1.00	10
6.4	0.156	0.980	15

IB vertical and horizontal

f (Hz)	T (secs)	R. M.	A. T. (±%)
0.1	10	0.00376	20
0.2	5	0.0248	15
0.3	3.3	0.0931	10
0.4	2.5	0.208	10
0.5	2.0	0.364	5
0.7	1.43	0.675	5
1.0	1.00	1.00	0
1.5	0.67	1.22	5
2.0	0.50	1.34	5
3.0	0.33	1.32	10
5.0	0.20	1.19	15
7.0	0.143	1.00	20

LP_1 vertical and horizontal

f (Hz)	T (secs)	R. M.	A. T. (±%)
0.01	100	0.246	20
0.0125	80	0.377	20
0.0167	60	0.589	15
0.02	50	0.745	15
0.025	40	0.899	10
0.033	30	1.06	5
0.04	25	1.00	-
0.05	20	0.872	7
0.0677	15	0.506	15
0.10	10	0.173	30
0.143	7	b	c

Key

SP	- Short-period seismograph
BB	- Broad-band seismograph
IB	- Intermediate-band seismograph
LP	- Long-period seismograph
R. M.	- Relative magnification
A. T.	- Amplitude tolerance
LP_1	- Long-period seismograph, wide response
LP_2	- Long-period seismograph, narrow response
b	- Measurement due to interference from microseismic background noise
c	- Tolerances not established

LP_2 vertical and horizontal

f (Hz)	T (secs)	R. M.	A. T. (±%)
0.01	100	0.046	c
0.0125	80	0.080	c
0.0167	60	0.170	c
0.02	50	0.270	c
0.025	40	0.440	c
0.033	30	0.780	c
0.04	25	1.00	c
0.05	20	1.06	c
0.0677	15	0.690	c
0.10	10	0.135	c

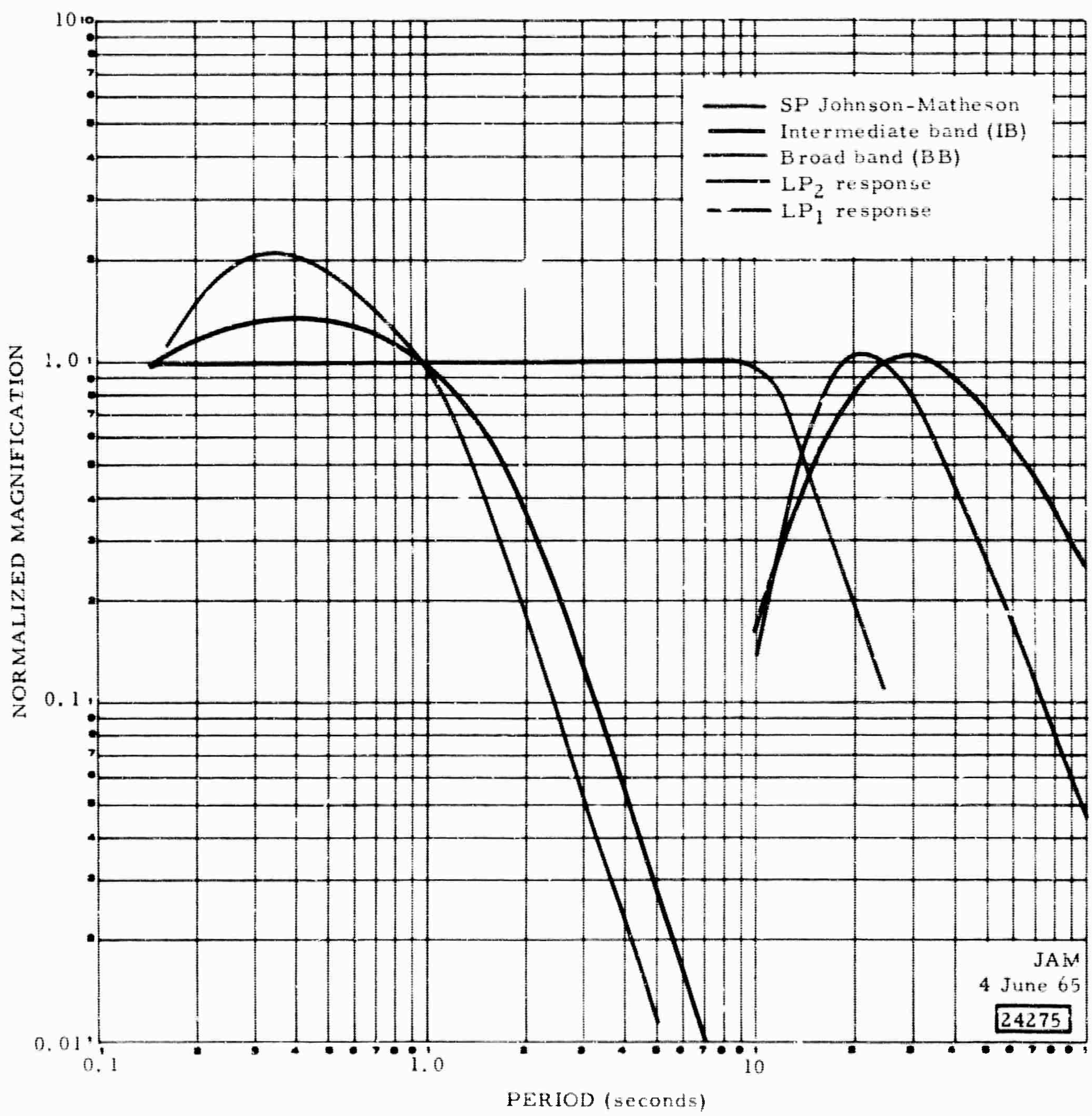

Figure 1. Present normalized frequency responses of seismographs at WMSO

Instrument	G	Instrument	G
Z5	0.362	Z13	0.355
Z6	0.355		
Z7	0.356	NSP	0.348
Z8	0.356	ESP	0.361

Additional motor constant tests were conducted on Z2 and Z11 during January 1965 and on the three-component short-period system during May. Data from Z2 and Z11 are given in section 7.2 Motor constant data for the three-component seismograph are as follows:

Instrument	G as found	G after adjustment
Z6	0.337	0.355
NSP	0.355	0.355
ESP	0.336	0.352

2.1.3 Motor Constants for Long-Period Seismographs

Motor constants of the long-period system were tested and adjusted in November 1964, just prior to this reporting period. In March 1965, as a part of the vault improvement program, the old spiral-four cable leading into the vault was replaced with new multiconductor cable. Motor constants determined with the calibration signal routed through this new cable have values approximately 15 percent higher than the standard value, indicating the extent of the leakage in the old cable.

After improvement of the vault and completion of the long-period system tests in April, the motor constants of the seismographs were adjusted to the standard value of 0.0158 newton/ampere. Following are the results of long-period motor constant determinations:

Instrument	G as set in Nov 64	G as found in Mar 65	G as set in Apr 65
ZLP	0.0160	(0.0187) 0.0159[a]	0.0158
NLP	0.0161	(0.0186) 0.0158[a]	0.0158
ELP	0.0160	(0.0187) 0.0159[a]	0.0158

[a]Corrected (15 percent) for minor leakage path in the old spiral-four calibration cable.

2.1.4 Motor Constants for Intermediate-Band and Broad-Band Seismographs

The motor constants of the broad-band system were tested and adjusted in December 1964. The following month, the motor constants of the intermediate-band system were determined. The results of these tests follow:

Instr	Previous G	G as found	Percentage change in G	G after adjustment
ZIB	0.126	0.126	0.0	0.126
NIB	0.631	0.690	+9.3	0.631
EIB	0.631	0.631	0.0	0.631
ZBB	2.84	3.31	+16.5	2.86
NBB	4.27	4.70	+10.0	4.26
EBB	4.29	4.26	-0.7	4.26

2.1.5 Degaussing of Calibration Coils

As a routine procedure, the calibration coils of all short-period seismographs are degaussed before checking the motor constants of the calibrator coils. On 27 May, the calibration coils of all short-period seismographs were degaussed after a severe electrical storm occurred the previous night. Table 3 shows the percentage of change in G that has occurred since the last G check. In the future, all short-period calibration coils will be degaussed after electrical storms as a routine procedure.

Table 3. Percentage change in G after degaussing

SP instrument	Date of last G check	Degaussing factor (percentage)
Z1	2 Nov 64	-2.1
Z2	14 Jan 65	-1.2[a]
Z3	28 Oct 64	0
Z4	9 Nov 64	-6.5
Z5	29 Oct 64	-1.7
Z6	28 Oct 64	-2.8
Z7	28 Oct 64	+12.4
Z8	28 Oct 64	-7.4
Z9	28 Oct 64	-5.8

Table 3. Percentage change in G after degaussing, Continued

SP instrument	Date of last G check	Degaussing factor (percentage)
Z10	29 Oct 64	0
Z11	14 Jan 65	-0.54[a]
Z12	28 Oct 65	+3.8
Z13	26 May 65	-1.7
NSP	25 May 65	-1.7
ESP	25 May 65	0

[a]No measurable change in G expected because the new JM calibrator is used in these instruments.

2.2 OUTAGES CAUSED BY ELECTRICAL STORMS

Twelve lightning storms occurred at WMSO between 1 December 1964 and 31 May 1965. On several occasions these storms resulted in damage to the instrumentation at the observatory. Table 4 shows the distribution of these storms and the damage that resulted to the instrumentation. In addition to the damage caused by the storms, data were lost five times because of blown fuses and/or flipped galvanometers. No seismometers were damaged by lightning during this period.

Table 4. Number of occurrences and extent of damage produced by lightning storms at WMSO from 1 December 1964 through 31 May 1965

	Dec	Jan	Feb	Mar	Apr	May	Total
Number of storms	0	0	1	1	5	5	12
Number of galvanometers damaged	0	0	1	0	1	1	3
Number of PTA power supplies damaged	0	0	0	0	0	0	0
Number of galvanometers flipped and/or blown fuses	0	0	1	0	3	1	5

2.3 DATA CHANNEL ASSIGNMENTS AND STANDARD OPERATING MAGNIFICATIONS OF SEISMOGRAPHS

In compliance with AFTAC specifications, each data format recorded is assigned a data group number. When a data format is changed, a new data group number is assigned to the new format. All of the data formats and their data group numbers recorded during the reporting period are listed in table 5.

Standard operating magnifications are assigned to each seismograph system based on the microseismic noise level observed on the particular system. er these standards are established, the magnifications of the seismographs e maintained within specified tolerances. The standard operating magnifications and the magnification tolerances are shown for each standard seismograph in table 6. Standard magnifications and tolerances have not been established for the experimental seismographs; therefore, these instruments are not included in the table. The stability of the magnification of the standard WMSO seismographs is shown in table 7. Stability data for the SP seismographs indicate that an excessive number of adjustments are required to maintain the ±5 percent tolerances on the seismometer. It is therefore recommended that the tolerances be increased to ±8 percent (460K to 540K). Data on the LP seismographs indicate that few adjustments are required to maintain their ±15 percent tolerances. When the present LP tests and evaluations have been completed, consideration will be given to reducing the LP tolerances to ±10 percent.

2.4 COMPONENT FAILURE REPORTS

A procedure for reporting component failures was adopted in December 1963. After a short trial period this system has been fully operational since 1 January 1964.

A special IBM card (form 273) was designed for use in reporting component failures. It was hoped that data written on this card at an observatory could be keypunched onto the same card in Garland. Because uniform coding of data is required, this proved to be impractical. The data reported on form 273 are now code Garland before being punched onto standard 80-column IBM cards.

The keypunch format used to store these data is given in appendix 2 of TR 64-118. This format includes the revisions given in the letter report of 17 March 1965 and, therefore, supercedes all other formats.

Table 5. Data channel assignments and normal operating magnifications of seismographs at WMSO

MAGNETIC-TAPE RECORDERS

No. 1		No. 2							
Channel	Data Group 3028 1 Dec 64-31 May 65	Channel	Data Group 3032 1 Dec 64-4 Dec 64	Data Group 3034 5 Dec 64-29 Dec 64	Data Group 3036[a] 10 Dec 64-5 Jan 65	Data Group 3038 6 Jan 65-20 Jan 65	Data Group 3040[b] 17 Feb 65-7 April 65	Data Group 3044 8 April 65-11 April 65	Data Group 3045 12 April 65-14 April 65
1	TCMDG	1	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG
2	Z1	2	ZLP	ZLP	ZLP	ZLP	ZLP_2	ZLP_2	ZLP_2
3	Z2	3	NLP	NLP	NLP	NLP	NLP_2	NLP_2	NLP_2
4	Z3	4	ELP	ELP	ELP	ELP	ELP_2	ELP_2	ELP_2
5	Z4	5	NSP	NSP	NSP	NSP	NSP	NSP	NSP
6	Z5	6	ESP	ESP	ESP	ESP	ESP	ESP	ESP
7	Comp	7	Comp	Comp	Comp	Comp	Comp	Comp	Comp
8	Z6	8	ZIB	ZIB	ZIB	ZIB	ZIB	ZIB	ZIB
9	Z7	9	NIB	NIB	NIB	NIB	NIB	NIB	NIB
10	Z8	10	EIB	DW1	EIB	EIB	EIB	EIB	EIB
11	Z9	11	SPZ	DW2	ZBB	Test	ZBB	Test	Test
12	Z10	12	Z6	Z6	Z6	Z6	Z6	Z6	Z6
13	TF	13	SZ	DW	ZB	ZBB	ZBV	Test	Test
14	WWV & voice	14	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice

DEVELOCORDERS

	Fast-speed, 10 mm/minute				Slow-speed, 1 mm/minute	
	Primary data	Secondary data			Primary data	
Channel	Data Group 3003 1 Dec 64-31 May 65	Data Group 3029 1 Dec 64-8 March 65	Data Group 3042 9 March 65-31 May 65	Channel	Data Group 3029 1 Dec 64-8 March 65	Data Group 3041 9 March 65-31 May 65
1	V	V	V	1	A	W1
2	Z1	Z10	Z10	2	M	M
3	Z4	Z11	Z11	3	1/10 ZLP	ZLL_1
4	Z7	Z12	Z12	4	1/10 NLP	NLL_1
5	Z2	Z13	Z13	5	1/10 ELP	ELL_1
6	Z3	Q	Z6[c]	6	ZLP	ZLP
7	Z5	A	Z6L	7	NLP	NLP_2
8	Z[illegible]	B	ZBV	8	ELP	ELP_2
9	Z9	C	S	9	ZBB	ZBB
10	D	I	MS	10	NBB	NBB
11	TF_1	S	W1	11	EBB	EBB
12	T	T	T	12	Z6	Z6
13	Z6	IB	ZIB	13	WWV	WWV
14	N-S	NIB	NIB	14		
15	E-W	EIB	EIB	15		
16	WWV	WWV	WWV	16		

[a]Also used 21 Jan 65 to Feb 65

[b]Also used 15 April to 31 May 65

[c]Operating at high gain

KEY

Z	Amplified vertical short-period seismograph from a site identified by a suffix number
Z6L	Amplified vertical short-period low-gain seismograph - number denotes seismometer site
V	Unamplified vertical short-period seismograph
ZLP	Vertical long-period seismograph
ZLL	Vertical long-period low-gain seismograph
ZBB	Vertical broad-band seismograph
ZBV	Vertical broad-band flat-velocity seismograph
ZIB	Vertical intermediate-band seismograph
NSP	Amplified north-south short-period seismograph
NLP	North-south long-period seismograph
NLL	North-south long-period low-gain seismograph
NBB	North-south broad-band seismograph
NIB	North-south intermediate-band seismograph
ESP	Amplified east-west short-period seismograph
ELP	East-west long-period seismograph
ELL	East-west long-period low-gain seismograph
EBB	East-west broad-band seismograph
EIB	East-west intermediate-band seismograph
SZ	Amplified vertical short-period seismograph
SPZ	Short-period vertical seismograph for special strain tests
DW	Deep-well seismograph
ΣT	Summation of all 13 short-period array seismographs
ΣTF	ΣT filtered
ΣS	Summation of Z1 through Z10
ΣSF	ΣS filtered
ΣA	Summation of Z1, Z2, Z3, and Z4
ΣB	Summation of Z4, Z5, Z6, and Z7
ΣC	Summation of Z7, Z8, Z9, and Z1
ΣD	Summation of Z10, Z11, Z12, and Z13
ΣI	Summation of Z1, Z2, Z3, Z5, Z6, Z8, Z9, Z12, and Z13
ΣQ	Summation of Z1, Z3, Z5, and Z9
A	Anemometer - wind speed only
W1	Anemometer - wind speed and direction
M	Microbarograph
WWV	Radio time
STS	Primary and secondary timing only
TCMDG	Time code management data group
Comp	Compensation
Test	Test instrumentation

Table 6. Standard operating magnifications and magnification tolerances for the standardized seismographs at WMSO

Short-period system		
Component	Standard operating magnification at 1 Hz	Magnification tolerances
Z 1	500K	±5%
Z 2	500K	±5%
Z 3	500K	±5%
Z 4	500K	±5%
Z 5	500K	±5%
Z 6	500K	±5%
Z 7	500K	±5%
Z 8	500K	±5%
Z 9	500K	±5%
Z 10	500K	±5%
Z 11	500K	±5%
Z 12	500K	±5%
Z 13	500K	±5%
NSP	500K	±5%
ESP	500K	±5%
VH	60K	±5%
VL	5K	±5%
ΣS	1000K	±5%
ΣT	1000K	±5%
ΣTF	3000K	±5%
ΣA	500K	±5%
ΣB	500K	±5%
ΣC	500K	±5%
ΣD	500K	±5%
ΣQ	500K	±5%

Intermediate-band system		
Component	Standard operating magnification at 1 Hz	Magnification tolerances
ZIB	100K	±10%
NIB	100K	±10%
EIB	100K	±10%
	Broad-band system at 0.8 Hz	
ZBB	2.5K	±10%
NBB	2.5K	±10%
EBB	5K	±10%
	Long-period system at 0.04 Hz	
ZLL	3K	±15%
NLL	3K	±15%
ELL	3K	±15%
ZLP	20K	±15%
NLP	20K	±15%
ELP	20K	±15%
ZLP_2	50K	±15%
NLP_2	50K	±15%
ELP_2	50K	±15%

Table 7. WMSO seismological operational magnification stability, December 1964 through May 1965

	Percent deviation												Average deviation	Required recalibrations												
	December		January		February		March		April		May			December		January		February		March		April		May		
	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-31	1-15	16-31		1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-31	1-15	16-31	Total
Z1	3.8	3.0	1.6	1.9	2.4	3.1	3.9	1.1	3.4	4.6	4.6	3.4	3.4	3	2	0	0	1	2	3	3	6	5	3	1	29
Z2	4.8	2.8	3.9	5.6	8.1	4.9	3.4	2.0	2.5	3.1	2.3	3.5	3.9	4	2	4	5	8	6	2	0	0	5	1	1	38
Z3	2.6	1.3	2.6	3.2	[illegible]	4.0	2.3	2.7	2.9	3.4	2.3	2.1	2.7	1	0	1	3	0	2	0	0	1	1	1	1	11
Z4	3.4	2.7	2.3	3.4	3.5	3.6	3.0	2.0	1.9	4.5	2.1	3.5	3.0	3	0	0	2	2	2	0	0	6	4	0	1	20
Z5	4.9	3.7	1.9	4.0	3.4	4.3	3.1	3.0	3.9	3.3	3.5	4.5	3.6	8	3	0	5	3	2	0	2	4	1	2	1	31
Z6	4.2	3.2	4.3	2.1	6.1	5.0	3.0	3.1	2.0	1.9	4.4	2.6	3.5	4	3	4	0	4	4	1	1	1	3	4	2	31
Z7	3.6	3.5	3.1	2.7	3.5	4.8	2.3	3.7	3.9	3.8	3.6	6.1	3.7	3	2	1	0	3	2	1	2	6	3	3	6	32
Z8	1.4	3.2	2.1	1.4	2.6	3.4	2.5	2.2	4.5	3.7	2.6	5.8	3.0	1	1	0	0	1	1	1	0	3	1	0	5	14
Z9	3.8	2.6	1.7	4.6	4.2	3.2	2.8	2.5	3.8	4.0	3.7	5.4	3.5	5	0	0	4	3	1	1	0	[illegible]	3	1	7	26
Z10	3.4	2.6	3.0	4.1	2.6	6.5	3.8	4.1	3.4	4.4	7.2	7.0	4.4	3	3	2	1	1	4	2	2	5	6	6	6	41
Z11	3.2	2.8	3.6	3.1	3.5	3.3	3.7	3.9	2.9	2.9	4.2	3.9	3.4	2	1	1	1	2	0	0	1	3	0	3	3	17
Z12	3.9	2.9	3.2	3.2	4.4	1.8	4.5	3.9	3.0	4.5	4.2	3.7	3.6	3	2	2	1	5	0	5	3	4	5	1	3	34
Z13	3.3	2.1	2.4	5.4	6.4	7.0	4.0	2.7	2.3	6.1	3.5	3.4	4.0	2	1	0	4	5	2	3	2	4	4	2	3	32
NSP	3.8	3.1	3.1	1.0	2.4	2.5	1.6	1.9	1.9	3.5	17.3[b]	12.4	4.4	3	0	1	0	0	0	0	0	0	10	11	9	34
ESP	7.2	3.2	2.4	2.8	6.5	4.1	4.2	3.8	1.9	3.3	2.7	4.3	3.1	3	0	1	1	2	3	3	2	0	0	1	1	17
ZIB	5.9	3.2	3.2	6.9	2.9	3.2	2.5	6.6	3.9	6.6	7.0	14.6	5.5	1	0	7	1	1	0	0	2	1	4	1	4	22
NIB	3.3	2.3	2.9	1.5	4.8	3.4	5.0	7.5	4.6	10.0	18.0[b]	10.0	6.1	1	1	1	0	2	1	[illegible]	[illegible]	4	6	8	5	31
EIB	4.3	4.1	2.6	2.7	2.6	5.4	5.4	6.7	3.0	[illegible]	3.1	2.8	3.7	0	2	0	0	0	1	[illegible]	1	3	0	0	1	11
ZLP	6.1	2.6	3.0	1.9	3.4	2.6	4.0[a]	10.0[a]	5.2	9.0	3.8	21.6	5.9	0	0	0	0	0	0	0	0	0	0	0	0	0
NLP	5.7	4.3	1.5	7.2	2.0	4.7	26.4[a]	5.0[a]	4.0	7.4	7.8	8.8	7.1	0	0	0	0	0	0	0	0	0	0	0	0	0
ELP	2.9	7.0	2.9	8.2	4.6	4.8	4.2[a]	7.3[a]	3.3	7.5	3.8	3.9	5.0	0	0	0	0	1	0	0	0	1	0	0	0	2
ZBB	1.4	3.1	1.3	1.3	7.3	1.5	4.1	5.9	8.6	7.9	4.2	14.4	6.2	0	0	0	0	0	0	0	2	0	0	0	1	3
NBB	4.5	2.8	2.2	3.3	3.9	5.3	3.3	5.3	8.3	7.0	1.2	2.14	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0
EBB	7.5	3.0	5.2	14.5	10.6	5.0	4.5	7.0	5.9	6.2	1.3	4.52	6.3	0	0	0	3	0	0	0	1	0	0	0	0	1
														50	23	25	28	44	32	28	24	53	61	48	61	477

[a]Testing on long-period system during this period
[b]Galvo balance in Develocorders off

Form 273 and the keypunch format have proved adequate for itemizing component failures at the observatories; however, no means is provided to record losses of data when the failures of components are not involved. Typical and frequent examples of this are jammed film in Develocorders and open lines caused by failures of lightning protection fuses.

Program MISERABLE has been written to process some of the data stored on punched cards. This program sums the outage times and repair times for particular pieces of equipment and prints out the numbers of components involved. A copy of this program was sent to the Project Officer and to SDL at the request of the Project Officer.

2.5 CALIBRATION OF TEST EQUIPMENT

In order to maintain the desired operational specifications of the instrumentation at WMSO, all test equipment is sent to the Garland laboratory regularly for calibration and testing. During this reporting period, all WMSO test equipment was calibrated in Garland and returned to the observatory.

2.6 SHIPMENT OF DATA TO SEISMIC DATA LABORATORY

WMSO magnetic-tape seismograms from 1 November 1964 through 31 May 1965 were shipped to SDL during this reporting period. Magnetic-tape seismograms are shipped to SDL with the regular LRSM shipment of data about 15 days after the end of the month during which they were recorded.

All 16-mm film seismograms recorded at WMSO from 1 November 1964 through 31 March 1965 were sent to SDL. The primary and secondary SP and the primary LP 16-mm film seismograms and their corresponding operating logs are shipped to SDL as soon as the data for the monthly five-station earthquake bulletin and routine microseismic noise curves are compiled.

2.7 SECURITY INSPECTION

Because WMSO holds a Department of Defense SECRET facility clearance, periodic inspections of the observatory are made by Government personnel. During March, Mr. Joseph Keltner, Industrial Security Specialist, Central Contract Management Region, USAF, inspected WMSO. The security precautions taken at the observatory were found to be satisfactory.

2.8 REVISION OF CALIBRATION PROCEDURES

In June 1963, a request was received from AFTAC to review the proposed AFTAC "Standardization of Calibration Procedures" for VELA-UNIFORM observatories. These procedures were reviewed by the Geotech staff. As a result, changes in the procedures were recommended in a letter report to AFTAC dated 14 August 1963.

Early in October 1963, we received a copy of Seismograph Calibration Standards, Project VELA-UNIFORM, AFTAC Technical Report VU-63-5. The procedures were adopted on 10 October 1963, as requested by the Project Officer.

In general, the procedures proved to be satisfactory for routine use. After the observatories had been operated for 10 months using these procedures, they were again reviewed by the Geotech staff. On the basis of this review, changes in the standards and in the logs were recommended in TR 64-118 and approval of the recommendations was requested in a letter report to AFTAC dated 26 January 1965.

Early in April 1965, we received a copy of Revision to Seismograph Calibration Standards from AFTAC. This letter changed some of the standards and logs established in AFTAC Technical Report VU-63-5. As requested, the revised calibration standards were adopted on 6 April 1965. The new logs are being adopted as the stocks of the old ones become exhausted.

The changes in calibration standards are given below:

a. In the monthly special calibration to check the frequency responses of the short-period seismograms, calibrations at 8 Hz and at 10 Hz have been deleted from the table of frequencies.

b. In the similar calibration for long-period seismographs, the calibration current may be increased by a factor of 5 at 0.1 Hz and a factor of 10 at 0.143 Hz relative to the current at the other frequencies.

c. In the daily calibration of long-period seismographs, the table of equivalent ground motions has been revised to include 0.5 micron for magnifications above 45K.

The four calibration logs have been revised and examples of the revisions will be included in the final report of Project VT/1124.

3. EVALUATE DATA AND PROVIDE MOST EFFECTIVE OBSERVATORY POSSIBLE

3.1 QUALITY CONTROL OF WMSO SEISMOGRAMS

3.1.1 Sixteen-Millimeter Film Seismograms

Short-period and long-period 16-mm film seismograms and the completed analysis sheets are routinely checked and critiqued in Garland on a random basis. Following is a list of the major items that are checked by the quality control analyst:

a. Neatness and completeness of film box markings;

b. Completeness, accuracy, and legibility of calibration and operation logs;

c. Quality of the overall appearance of the record (e.g., trace spacing, trace intensity, proper film processing);

d. Completeness, accuracy, and legibility of the data entered on the analysis form.

When the quality control check has been completed, a critique, the seismograms, the logs, and the analysis sheets are returned to WMSO for review by observatory personnel.

3.1.2 Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms from each magnetic-tape recorder at WMSO are made in Garland to assure that the recordings meet specified standards. Following are some of the items that are checked by the quality control group:

Tape and box labeling
Accuracy, completeness, and neatness of logs
Adequate documentation of logs by voice comments on tape
Seismograph polarity
Level of calibration signals
Relative phase shift between array seismographs
Level of the microseismic background noise
Level of the system noise

Dc balance of PTA
Oscillator alignment
Quality of the recorded WWV signal
Time pulse carrier
Digital time marks

3.2 INSTALLATION OF TELEMETRY EQUIPMENT

During this reporting period, arrangements were made to initiate the transmission of seismometric data to MIT Lincoln Labs in Cambridge, Massachusetts. Telemetry equipment was procured from TFSO and installed by representatives from MIT. Telemetering of data from the six points and also the center of the Star-of-David array at WMSO began on 30 March. Since March, transmission of data has been interrupted only once when a farmer cut the cable with his plow at a point between Lawton and Oklahoma City.

3.3 IMPROVEMENTS TO LP SEISMOGRAPH

A program of improvements to the LP seismograph was initiated during this reporting period. The program generally involves three basic goals:

a. To reduce the system noise so that higher magnification can be attained;

b. To operate a three-component seismograph (LP2) whose frequency response is inverse to the noise (narrow response) to allow maximum gain in the band from 10 to 40 seconds where a large number of seismic signals occur;

c. To study the nonseismic noise and seismic signals at periods longer than 40 seconds by operating a three-component seismograph (LP1) with a frequency response that will emphasize the longer period signals (broad response).

3.3.1 Reduction of System Noise

System noise has been reduced by modifying walk-in vault No. 7 so that it is sealed from pressure fluctuations. A marine door with a rubber gasket was installed to seal the access to the vault, and sealing compound was used to eliminate leaks around the base of the pier. Necessary fittings were installed so that a gage and air compressor can be connected to check the time constant of air leakage and assure that the vault is sealed.

The installation of the pressure-tight door resulted in a leakage time-constant of 67 minutes. Additional sealing compound has improved the time-constant to better than 2 hours.

Controlled tests were conducted in May to determine the effects of vault sealing on system noise induced by atmospheric pressure fluctuations. These tests indicate noise reductions of approximately 3 dB on the horizontals and 1 dB on the vertical component of the LP system during 15-mph winds. Because vault sealing has eliminated the direct effects of atmospheric pressure fluctuations on the seismometers, the primary cause of the noise remaining on the horizontal traces during windy periods can probably be attributed to the effects of atmospherically induced disturbances in the surface of the earth.

Work is now in progress to move the PTA's to the long-period vault so that the low-level data signals will not be routed through field cables. This modification of the system will eliminate line noises and reduce the susceptibility of the system to lightning damage. After this work is completed, final system noise tests will be conducted and reported.

These tests and modifications are a part of a program of long-period improvements initiated in 1964 and reported in TR 64-118.

3.3.2 Dual Long-Period Seismograph Systems

To make the LP1 and LP2 seismographs operative, dual-output power supplies and a filter amplifier were installed as shown in figure 2. The filter amplifier is an engineering model consisting of commercial operational amplifiers and associated resistive-capacitive networks.

This unit provides dc decoupling in addition to the prescribed filtering action. The schematic of a typical channel is shown in figure 3. The two outputs for each seismograph are filtered differently to provide the LP1 and LP2 responses shown in figure 4. The LP2 system was placed in service at 50K magnification in February. As indicated by the seismogram in figure 5, the magnification of the LP2 system is limited by the amplitude of the 15-second microseisms. A filter is being designed which will reduce the response of the LP2 system at 15 seconds. When the filter is installed, it is expected that the system magnification can be increased to about 100K.

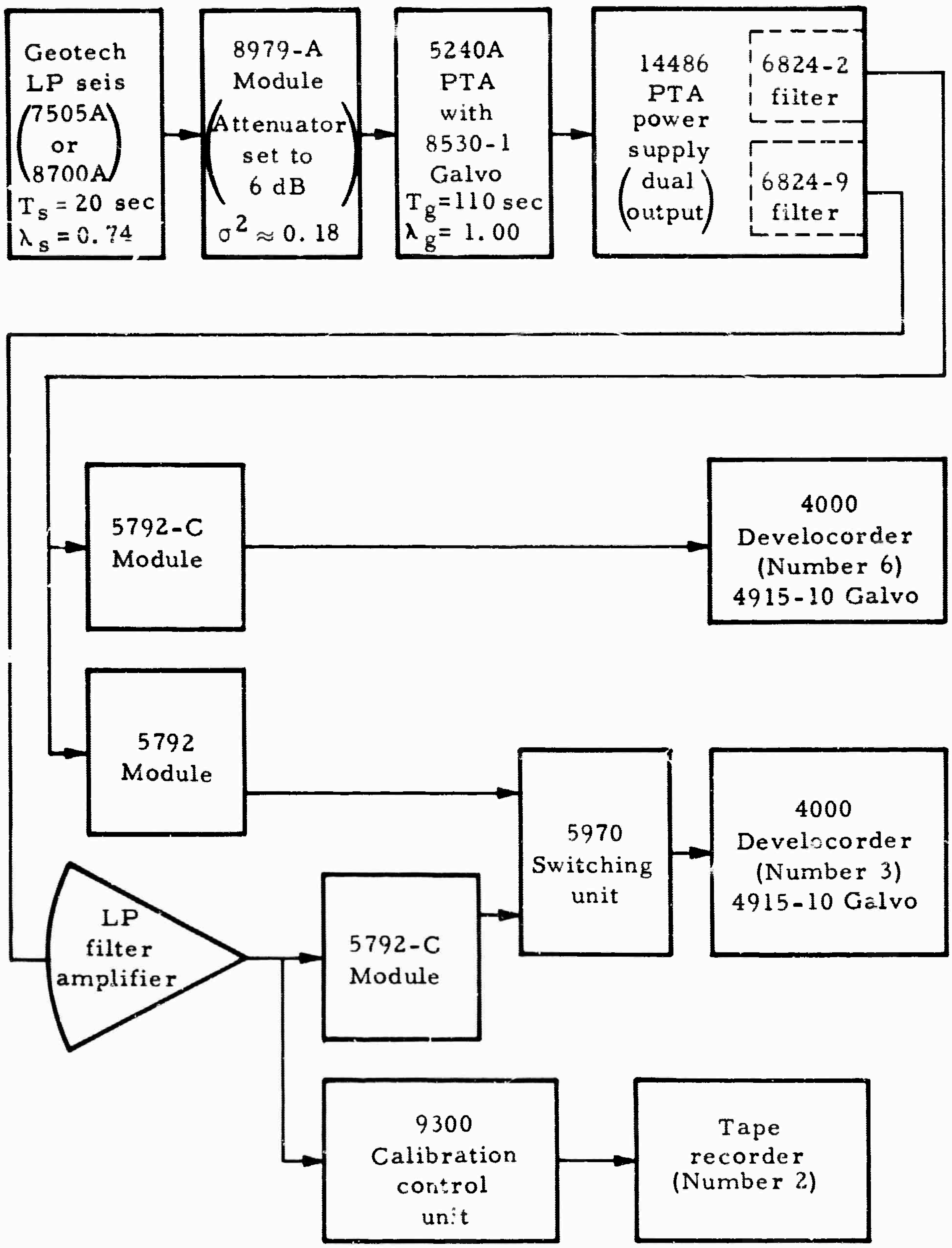

Figure 2. Block diagram for the three component dual-output long-period seismographs at WMSO

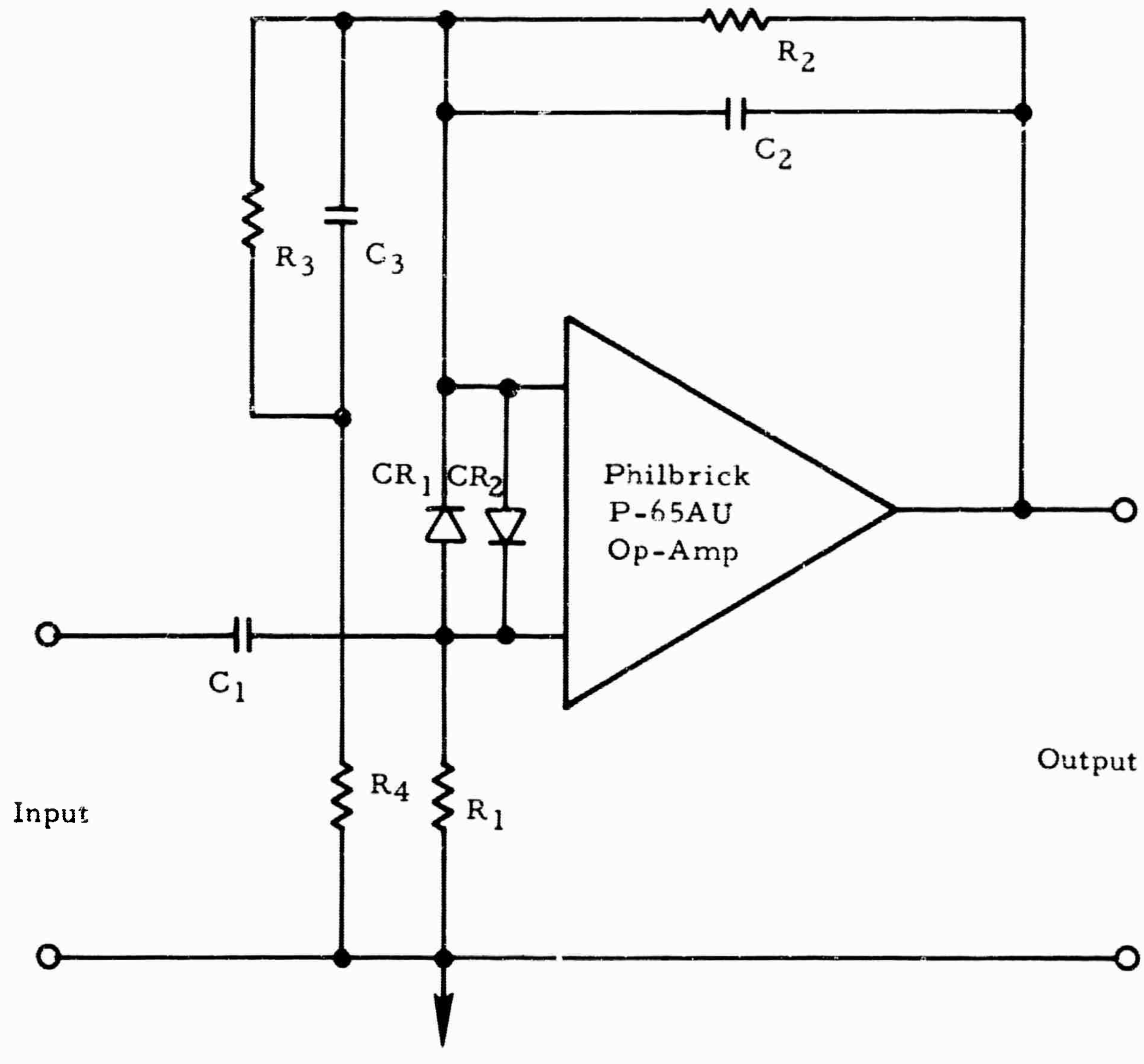

Figure 3. Simplified schematic for a typical channel of the filter amplifier for the long-period system at WMSO

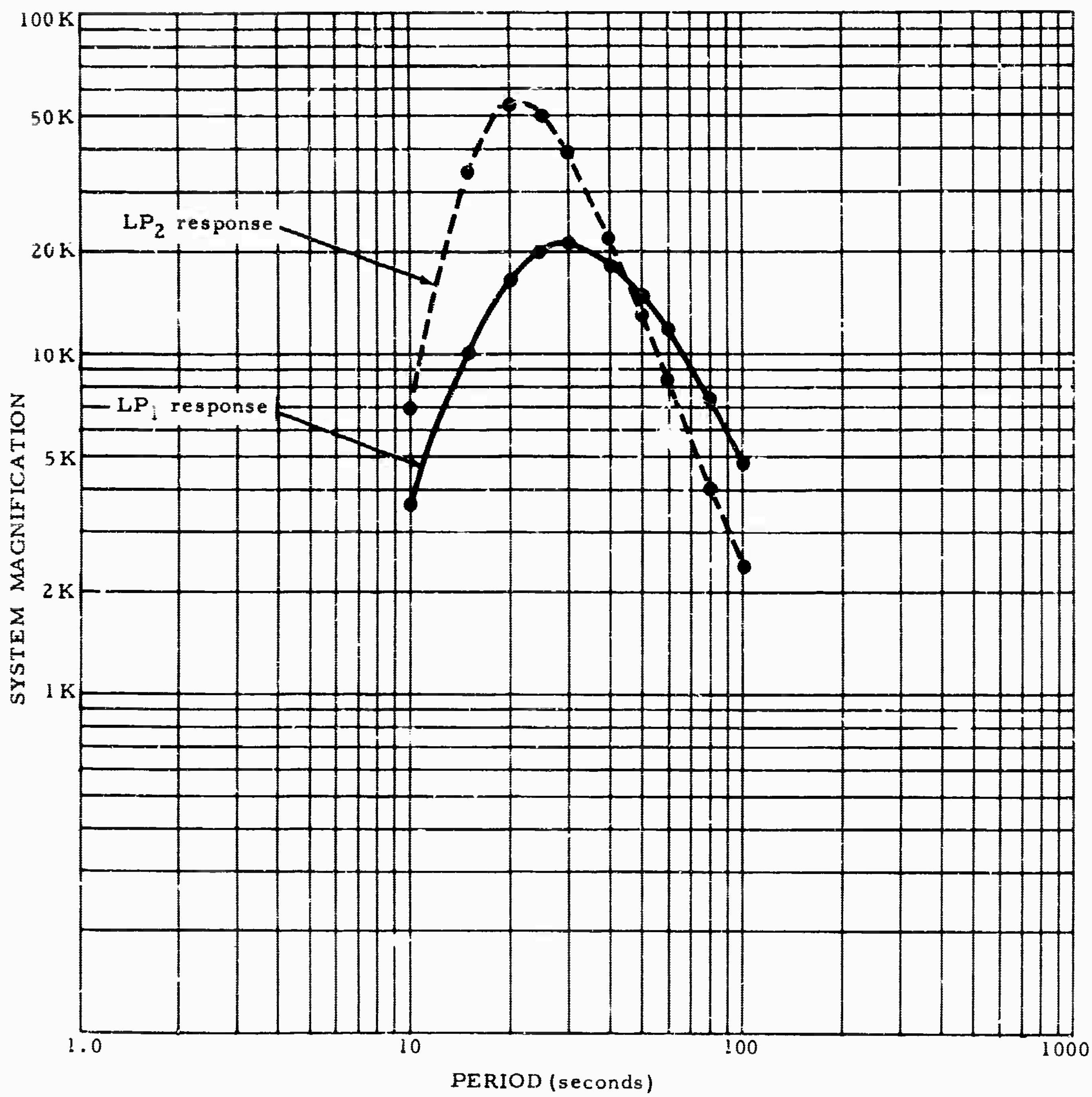

Figure 4. Frequency responses of the dual output long-period seismograph system at WMSO. The LP_1 system is recorded on Develocorder No. 6. The LP_2 system is recorded on Develocorder No. 3

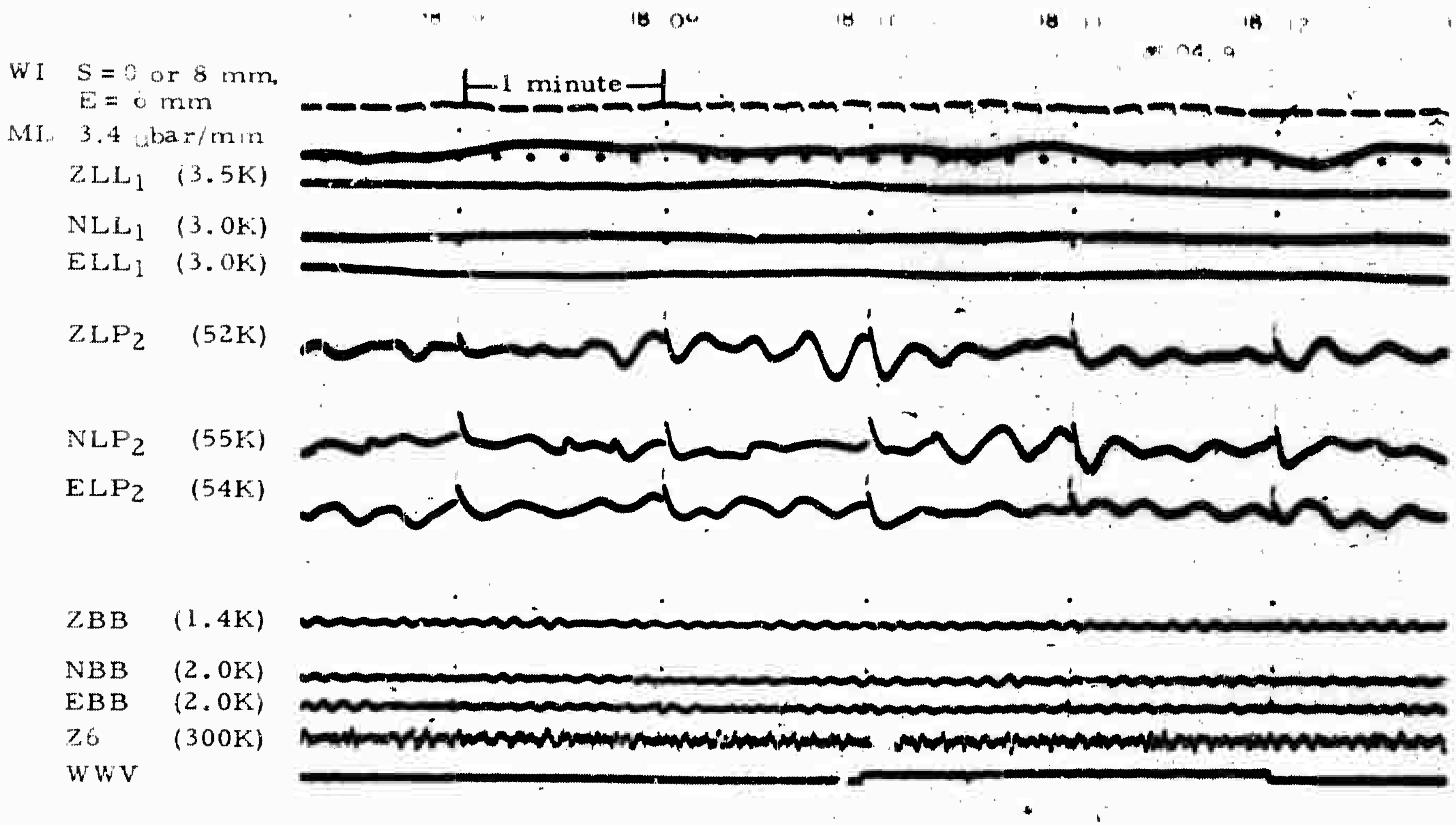

Figure 5. WMSO recording showing typical trace excursions on the new LP_2 seismographs. The recording magnification of this system is limited to approximately 50K by the 15-second microseisms. (X10 enlargement of 16-mm film)

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3.4 IMPROVEMENTS TO POWER SYSTEM

During the week of 11 April, the following changes were completed to improve the instrumentation power systems at WMSO:

a. The battery system was converted from a positive ground system (-12, -24 Vdc with respect to ground) to a more versatile system that has plus and minus 12 Vdc with respect to ground. Two battery cells were added to the battery bank, converting the 18-cell bank to the more standard 20-cell bank.

b. A new Dual Dc Regulator, Model 21427, was installed to regulate the voltage of the dc power supplied to the timing system and other critical instruments. This regulator will allow enough charging voltage to be supplied to the batteries to charge them to 100 percent capacity without exceeding the input limits of critical instruments.

c. A highly efficient Ac Voltage Regulator, General Radio Model 1570ALR, which was available from Project VT/1124, was installed to regulate the ac power generated during emergency conditions and to supply additional regulated power under normal conditions.

d. A 2-kVA Sola Constant Voltage Transformer was installed to prevent overloading of the present 3-kVA transformer. This will allow both tape recorders to be operated on regulated power. The 3-kVA transformer is used to power the two magnetic-tape recorders; the 2-kVA transformer is used to power the PTA's and certain instruments in the console.

e. The power circuits were modified so that only the primary and secondary fast-speed Develocorders are operational during emergency power conditions. This will prevent overloading of the dc to ac inverter and increase the duration of emergency power from the batteries. Because we plan to move the LP PTA's to the vault, where available commercial power (without backup) is believed to have better reliability than a power line (with backup) extended from the observatory, they will not be operational during emergency power conditions. The slow-speed Develocorder will also be inoperative during these conditions.

These changes provide increased power circuit distribution and better protection of each type of power supplied to operate the observatory equipment.

3.5 IMPROVEMENTS IN LIGHTNING PROTECTION CIRCUITS

The carbon block and fuse type of protection system in use at the VELA-UNIFORM Seismological Observatories has limitations. Two main faults are the losses of data caused by blown fuses and shorted carbon blocks, and inbalances produced in a system when one of a pair of carbon blocks breaks down.

Experimental lightning protection systems have been installed at WMSO and are presently being evaluated. The basic unit in these protection systems is a three-electrode gas-filled telecommunications line protector manufactured by Associated Electrical Industries, Ltd. (AEI); the model used is the type 16A. This protector essentially provides a discharge gap from line-to-line and from each line-to-ground. It has an arc-over voltage between 150 and 350 volts and, according to the manufacturer's specifications, operates in less than 1 microsecond. Its most important property is that approximately 1 microsecond after 1 of the 3 gaps is struck and energized in either polarity, the resulting ionization modifies the operating characteristics of the remaining 2 gaps. These gaps can then operate at greatly reduced voltages. The initial arc-over voltages and the speeds of operation of each of the three gaps are more consistent than can be expected by using separate two-electrode gas-filled protectors or air-gap protectors.

Type 16A protectors have been installed at WMSO at the input to the SP, BB, IB, and LP PTA's, and at the data and calibration coils of all SP seismometers. Experience has shown that these circuits are the most susceptible to lightning damage.

Installation was completed between 31 March and 18 May. Since the installation, there have been several violent sotrms at WMSO. The protection provided by the type 16A protectors during this period has been an improvement over the carbon block-fuse system. The total damage has been 1 PTA galvanometer suspension broken and 4 PTA galvanometers "flipped" (i.e., overdriven and caught behind its stop until manually released). The protectors from these damaged circuits have been examined in Garland and appear to be undamaged. Although the AEI protectors have afforded much improved protection for the various circuits, the problem of "flipped" galvanometers still causes some loss of data. We believe that protection can be further increased by the use of inductances and/or faster operating diodes in the circuits associated with the AEI protectors. This will be tested.

3.6 INSTALLATION OF TIMING SYSTEM, MODEL 19000

The new Timing System, Model 19000, and Power Amplifier, Model 22183, were installed during February. During the installation, spurious changes of time, an erratic LP time-mark program, and damaged transistors in the power amplifier were encountered. The damaged transistors were caused by interaction between the positive-grounded power amplifier and the timing system when the time encoder outputs were connected to the single-ended tape recorder inputs. This problem was corrected by installing a transformer input circuit on the power amplifier.

The spurious time marks and changes of time were believed to be due to bad solder joints in the timing system. The unit was returned to the Garland plant where severe environmental tests were conducted to discover all potentially troublesome solder joints. Based on the results of these tests, it was decided to use a new split eyelet on the printed circuit boards in the system.

In February, the timing system was reinstalled at WMSO, where it operated satisfactorily. Successive adjustments during the remainder of the reporting period have resulted in a primary time drift rate of less than 0.5 millisecond per day.

3.7 MICROBAROGRAPH

Installation and final calibration of the new dual-output microbarograph was completed early in December 1964. The new and old systems were recorded simultaneously for comparison. On 7 December, the new microbarograph became the standard instrument. Recording of the old system was terminated and it was returned to Harry Matheson of the National Bureau of Standards, from whom it was on loan.

3.8 WATER CONTAMINATION

A reddish residue continues to be observed in the processing units and in the discharge lines of the Develocorders at WMSO. A special test was run on Develocorder No. 4 to determine if the use of distilled water would eliminate the residue. On 30 March, all chemical tanks, lines, and the processing unit were cleaned. Distilled water was used for chemical mix and film wash for 21 days with no obvious improvement. Following these tests, a commercial

fungicide (Aqua Aid), which is used in aquariums, was mixed with the water. This mixture also failed to yield favorable results. A sample of the residue has been returned to Garland for analysis.

3.9 ADDITION OF NEW PTA ROOM TO CRB

During February, we were notified by our Project Officer that modifications and additions planned for the observatory building at WMSO would not be made because of the high cost estimate submitted by the Corps of Engineers. Because this will not be done, we have started to replace the numerous spiral-four cables from the amplifier building to the observatory with multiconductor cable.

3.10 ADDITIONAL TAPE RECORDER

Recommendations for a third magnetic-tape recorder (a slow-speed unit) for WMSO were reviewed by the client during this reporting period and it was decided that an additional unit is not required at this time.

3.11 REPLACEMENT OF RECORD AND PLAYBACK HEADS FOR HONEYWELL TAPE RECORDER

New record and playback heads for the Honeywell recorder were installed and the old heads were returned to Garland. Between 0.006 and 0.008 inch of head wear was observed on the old heads. A check with the manufacturer revealed that the initial gap depth was 0.009 to 0.010 inch, and that heads are actually useable until the gap depth approaches zero. This indicates that after resurfacing, these heads should have from 1 to 2 years additional life for use as replacement heads at other observatories.

3.12 MODIFICATION OF 3-Hz GALVANOMETERS

Modifications to three, 3-Hz galvanometers were made under Project VT/4054 and field tests were begun at BMSO under Project VT/1124 as part of the evaluation of the pulse cancellation method of seismograph calibration. The galvanometers were modified so that their free period could be adjusted within a ± 10 percent range without removing it from the PTA. The modification was accomplished by extending a period adjustment mechanism through the galvanometer top cap. An escutcheon was cemented on the cap and indicates the relative resonant frequency. Figure 6 shows the modified galvanometer.

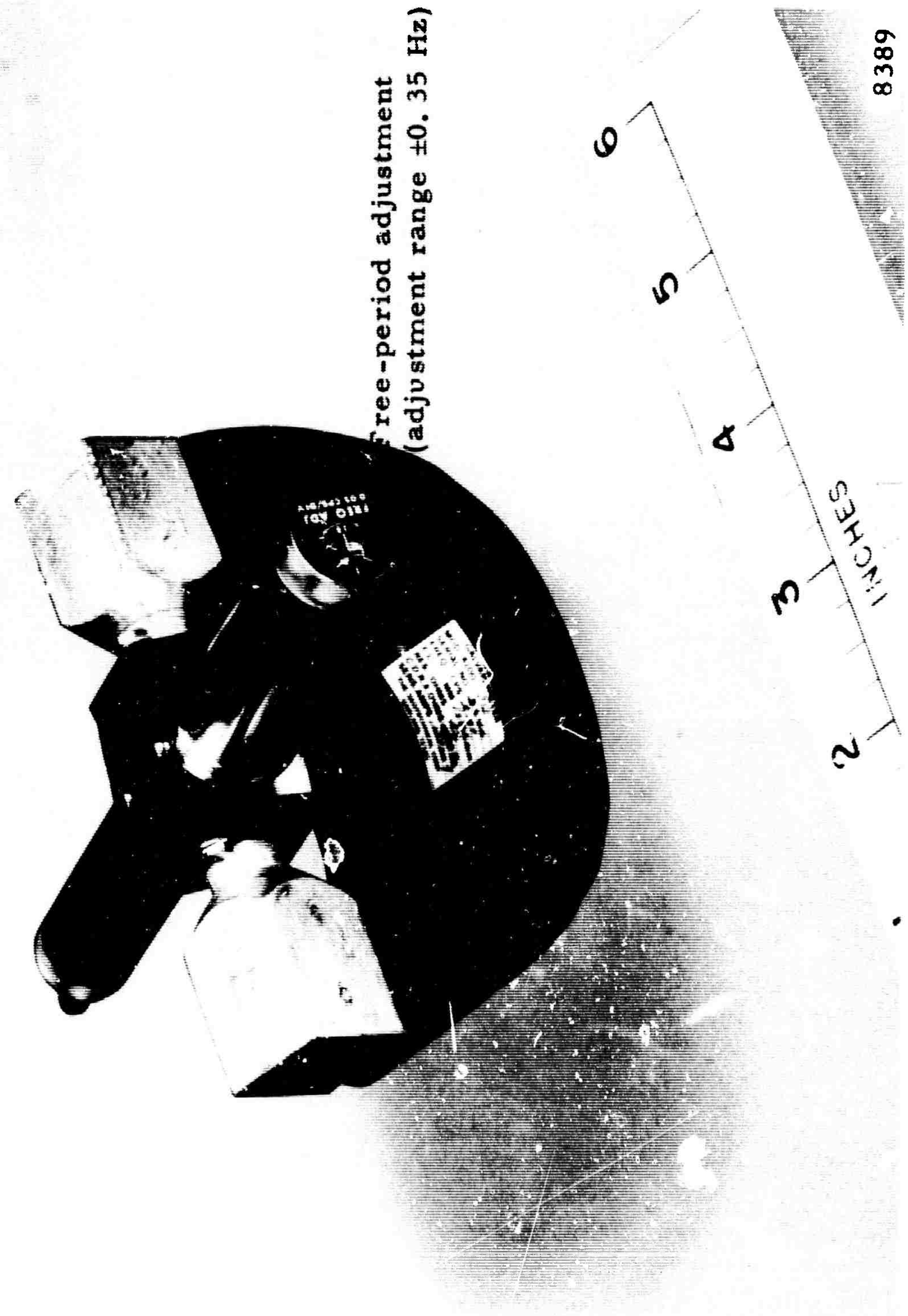


Figure 6. Modified Galvanometer, Model 4100-213

3.13 REDESIGN OF PTA TEST SET, MODEL 23930

During this reporting period, the design refinements of the PTA test set described in section 2.6 of TR 64-118 were completed. The test set will be delivered to WMSO for field testing in early June. Additional modifications, which may result from field use experience, can be done on a time schedule that will permit delivery of test sets to other observatories by 15 August 1965. Appendix 3 contains preliminary specifications for the test set.

4. TRANSMIT DAILY MESSAGE TO USC&GS

Messages sent to the Director of the USC&GS daily contain the arrival times, periods, and amplitudes of the principal P-wave phases of all naturally occurring events recorded at WMSO.

On weekdays, WMSO routinely transmits the daily message by TWX to the General Services Administration (GSA) operator in Oklahoma City, Oklahoma. The GSA operator relays the message to the USC&GS in Washington, D. C. On weekends and holidays when the GSA offices are closed, the WMSO message is transmitted to the USC&GS by commercial telegraph.

A list of the number of events of all types reported to the USC&GS by WMSO from 1 December 1964 through 31 May 1965 are included in table 8.

Table 8. Locals (L), near-regionals (N), regionals (R), and teleseisms (T) reported to the USC&GS by WMSO, 1 December 1964 through 31 May 1965

Month	L	N	R	T	Total events located by USC&GS	Percentage detection by WMSO and used by USC&GS
December	0	2	23	411	303	55.8
January	0	0	35	433	358	52.8
February	0	7	[illegible]5	1515	1030	69.1
March	0	3	19	765	a	a
April	0	5	30	672	a	a
May						

[a] Data for these months not available

5. PUBLISH MONTHLY EARTHQUAKE BULLETIN

Data from WMSO were combined with data from BMSO, CPSO, TFSO, and UBSO and published in a multistation earthquake bulletin. The bulletins for August through November 1964 were published during this reporting period. In addition, February data have been keypunched, transcribed on magnetic tape, and sent to SDL for processing. The September 1964 bulletin was the first edition compiled by the Automatic Bulletin Process (APB).

6. PROVIDE OBSERVATORY FACILITIES TO OTHER ORGANIZATIONS

6.1 The facilities and personnel of WMSO were made available to assist in research done under Project VT/5051 (Deep hole) and other projects. Following is a list of other authorized organizations whose representatives visited WMSO:

MIT Lincoln Labs, Cambridge, Massachusetts

New State Telephone Company, Lawton, Oklahoma

Southwestern Bell Telephone Company, Lawton, Oklahoma

Dr. Stephen Mueller, University of Berlin, Berlin, Germany

6.2 In addition to the daily reports to the USC&GS, WMSO notifies the Stanford Research Institute (SRI) of any earthquake that occurs within the continental limits of the United States. Notification and detailed information on 11 events were telephoned to SRI between 1 December 1964 and 31 May 1965.

7. INSTRUMENT EVALUATION

7.1 MELTON SYMMETRICAL TRIAXIAL SEISMOMETER (LP) TESTS

During this reporting period, preliminary field tests were begun at WMSO on the Melton Symmetrical Triaxial Seismometer (LP), Model 15560. The design

considerations of this instrument are described in TR 64-89, Melton Long Period Bore-Hole Triaxial Seismometer, Project VT/072. Because calibration circuits were not installed, the triaxial seismograph (TL) was equalized and set to a magnification of approximately 2,000 by a comparison of signals that were recorded on other LP systems. In addition to the three channel outputs of the instrument, a resistive summation of the three outputs was recorded to produce a simulated vertical seismogram. The frequency responses of the TL seismograph and that of the LP tripartite seismographs are shown in figure 7. Figure 8 shows the response of the TL seismograph to Love and Rayleigh waves from an earthquake at an epicentral distance of approximately 78 degrees.

Preliminary field tests of the engineering model at WMSO will be completed early in June 1965. Indications to date are that the seismometer is sensitive to temperature changes, and thus lacks adequate stability in the present installation to obtain further useful field test data. It was decided that further field testing should not be done until field operating difficulties have been analyzed by the designers and consequent modifications have been made.

7.2 NEW JM CALIBRATION ACTUATOR

In June 1964, a new calibrator (Calibration Actuator Kit, Model 18351), was installed in SP seismometer Z11 at WMSO; in July, a similar calibrator was installed in Z2. The new calibrator and its installation are described in section 6.6 of TR 64-118. Tests of the new calibrators were conducted at WMSO and on a similar unit installed in Z7 at CPSO. These tests consisted of a series of G checks taken at approximately 1-month intervals. The change in G from month to month was determined. As reported in TR 64-130, the results from the two observatories were contradictory. Results from CPSO exhibited a stable motor constant; those from WMSO contained significant deviations.

In December 1964, some doubt arose regarding the stability of the Remote Calibrator, Model 2520, used to measure the G of the new actuators at WMSO. Further checks revealed that the calibration control unit should be returned to Garland for recalibration.

The instrument was later returned to WMSO, and during January and February extensive tests were conducted in an effort to gather new motor constant data which could be used to evaluate the new JM calibrators. Motor constants were run on Z2 and Z11 with results shown in table 9. Except for the reading taken on 4 February on Z2, the G's remained quite stable.

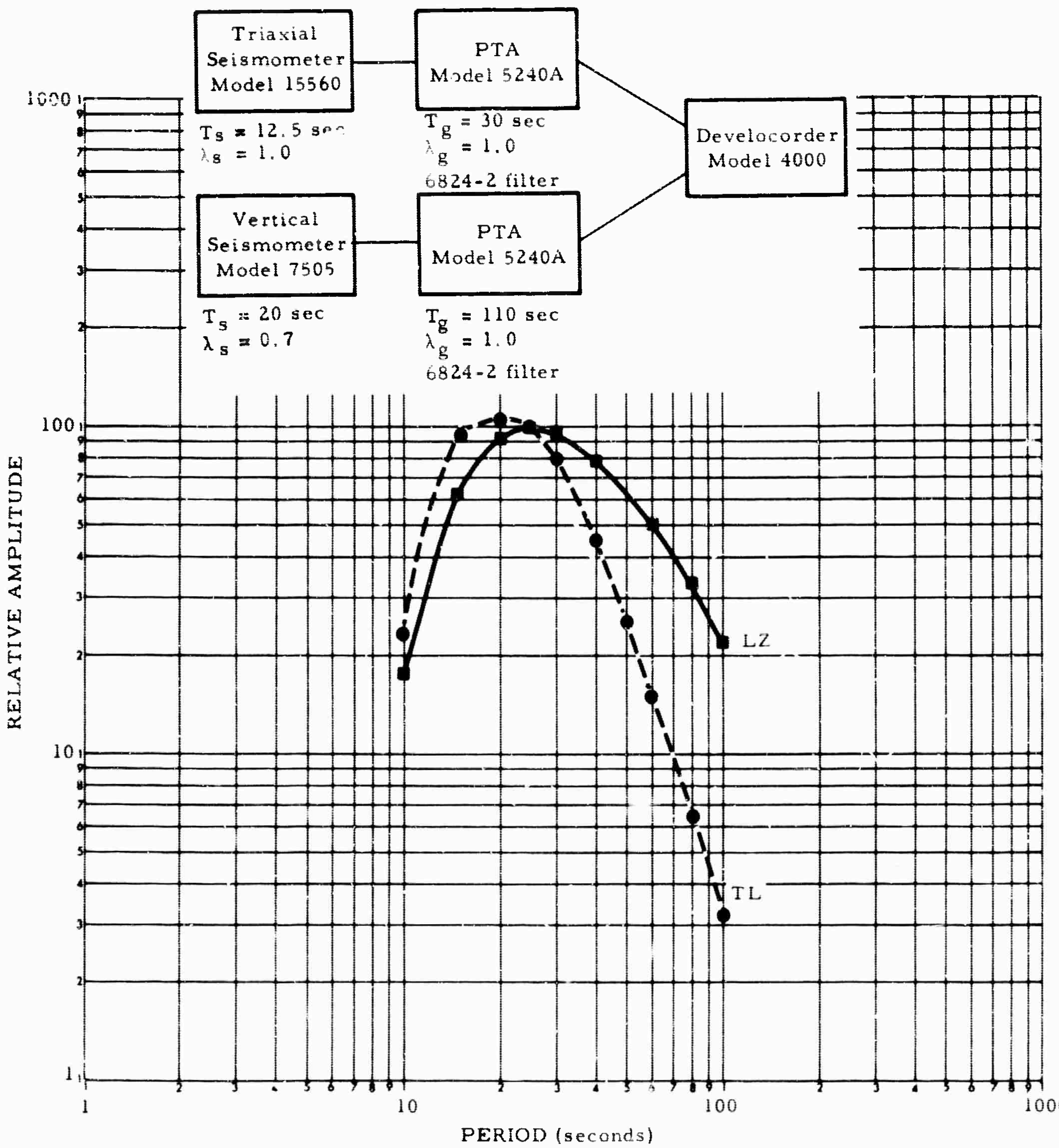
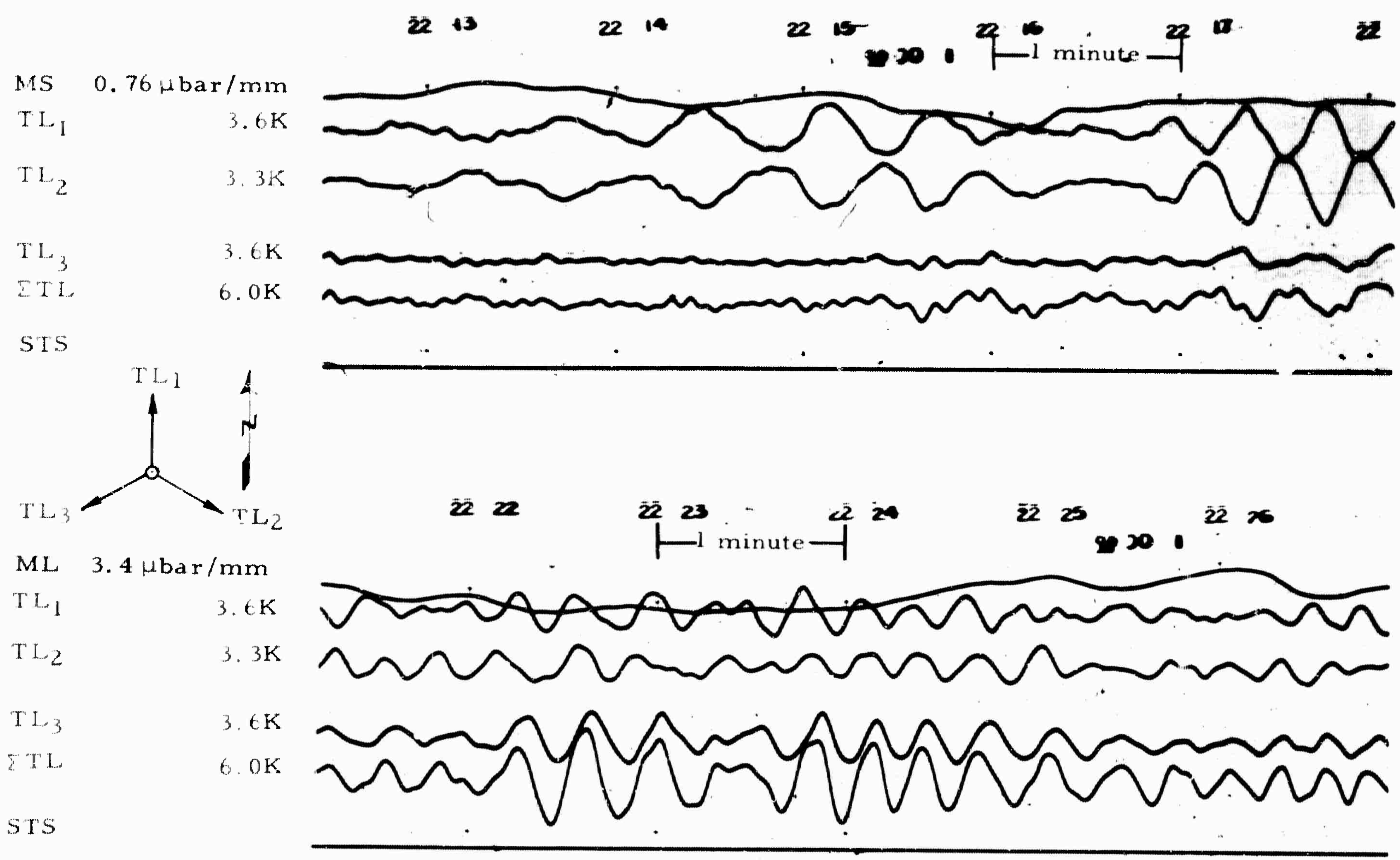


Figure 7. Relative response of the LP triaxial seismograph (TL) and the LP tripartite seismographs (LZ) as a function of period



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Run 001
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Figure 8. Experimental LP seismogram illustrating the response of the LP triaxial seismograph to Love and Rayleigh waves from a teleseismic earthquake. $\Delta \simeq 78$ degrees, azimuth $\simeq 60$ degrees. (X10 enlargement of 16-mm film)

Table 9. Motor constant data for Z2 and Z11

	Instrument	Initial G	Final G
January			
7	Z2	0.360	0.360
	Z11	0.368	0.355
14	Z2	0.359	0.359
	Z11	0.355	0.355
21	Z2	0.362	0.362
	Z11	0.355	0.355
28	Z2	0.362	0.362
	Z11	0.355	0.355
February			
4	Z2	0.350	0.354
	Z11	0.355	0.355
15	Z2	0.368	0.368
	Z11	0.355	0.355
19	Z2	0.366	0.356
	Z11	0.355	0.355

Simulated lightning strikes were applied on two separate dates. One test was conducted on 4 February by applying severe voltage spikes from the central recording building, and a second test was run on 15 February by applying the voltages at the input to the lightning protector at the seismometer. Voltages were raised to a maximum of 1600 volts with no apparent effect on the motor constants, although lightning protector fuses were blown in Z2 by one severe spike.

Monthly G checks were run on Z7, the seismometer at CPSO on which the new actuator was tested, from 28 July through 12 March. These tests indicated a maximum deviation in G of 2 percent (0.426 to 0.435).

During March at CPSO, the signal cables to Z7 were hit directly by lightning with no resulting damage to the calibrator. Approximately nine sections of the cable and associated lightning protectors were destroyed by this strike.

Satisfactory results from the recent motor constant tests at WMSO, coupled with the successful operation of the calibrator in Z7 at CPSO, indicate that the new JM calibrator exhibits a high degree of stability and is less susceptible to lightning damage than the calibrators presently used.

7.3 COMPARISON OF DEEP-HOLE AND SURFACE SEISMOGRAPHS

As reported in section 7.6 of TR 64-130, tests were being conducted to ompare the effects of wind noise on the deep-hole and the surface Benioff seismograph. Preliminary results indicated that there was very little difference in the responses when the wind speed is less than 30 mph. In the few instances where the wind speed exceded 30 mph indications were that the surface seismograph responded more to the wind than did the deep-hole instrument. Further comparisons were planned, but during December, the deep-hole group returned the deep-hole instrument to Garland. These tests have consequently not been completed.

7.4 AMPLIFIED WOOD-ANDERSON SEISMOGRAPH

Operation of the Wood-Anderson (WA) seismometers was continued during this reporting period, but comparison of its response and the response of the JM horizontal seismographs to signals has not been completed. Preliminary observations indicate that there is very little difference in the detection capability of the two seismographs for short-period shear waves when both seismographs are recorded at a magnification of about 100K. The WA seismometer-phototube amplifier system requires frequent maintenance if noise pickup in the recording channel is to be kept at a minimum value because of the fact that the outputs of the seismometer-amplifiers are recorded with minimum attenuation. Power line voltage fluctuations are especially evident if the response of the balanced stages of the amplifier become slightly unequal. Further evaluation of the response to signals has been delayed due to assignment of higher priority to other studies; however, this evaluation should be completed in approximately 2 months.

7.5 ARRAY PROCESSOR AND LISSAJOUS DISPLAY, MODEL 18621

Evaluation of the array processor and Lissajous display was begun in January using magnetic-tape playback as the input signal. It was determined that several modifications would be desirable in order to

assure increased operational dependability of this instrument in the field. Several repairs and minor modifications were accomplished during initial testing. The remaining problems which need correction are listed below:

a. Heat from the projector lamp produces excessive intensity change on the film due to changing temperature of the developer solution. The rate of film developing is difficult to adjust and maintain at the slower of the two film speeds due to excessive heat from the lamp.

b. The intensity, focus, and astigmatism controls for the recording cathode ray tube were moved from the front to the rear of the console so that the person viewing the spots during the focusing operation could adjust the controls. This change was made temporarily and needs to be made a permanent modification.

c. Numerous small malfunctions in the commutator and deflection circuits have been repaired; however, intermittent faults still occur. These circuits need to be given a complete inspection and reworking to increase reliability.

d. A means of focusing the film projector from the front of the console is needed.

An example of the Lissajous displ y feature is shown in figure 9. Interpretation of the particle motion in a plane, and/or relative phase between two sinusoids, (fi-ure 10) depends on the successful resolution of the time base separate from the motion displayed in the horizontal direction.

The WMSO array is too small to provide an adequate test of the capabilities of the time compensation feature. Figure 11 shows a recording of a close teleseismic P-wave signal uncompensated and compensated for travel time across the array. The difference can be easily seen in this example, but it is doubtful that any aid in visual detection capability can be obtained with time delays no greater than 0.05 to 0.2 second (the usual range of delays required for teleseisms recorded by an array the size of the WMSO array).

Sixty traces can be recorded simultaneously (figure 12), each with any given simulated time delay. The resolution is good, but not as good as might be needed if the larger amplitudes on adjacent traces were unrelated. The capability to monitor 60 separate data outputs is one of the more valuable characteristics of the time compensated display.

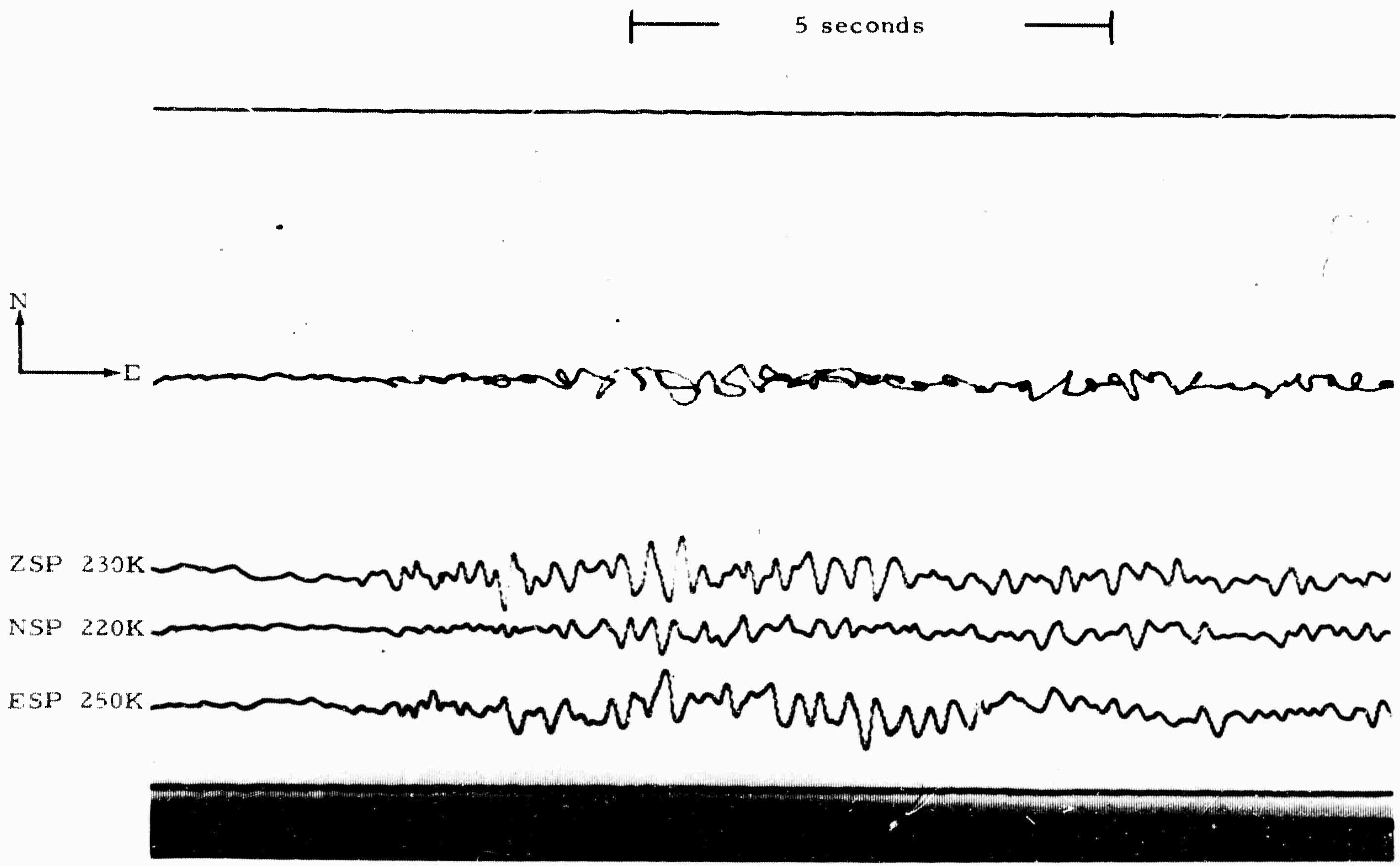


Figure 9. Lissajous display of a magnetic-tape playback of a P arrival from a near-regional quarry blast recorded on the Model 18621 array processor and Lissajous display (X10 enlargement of 16-mm film)

WMSO
27 Feb 64
Test

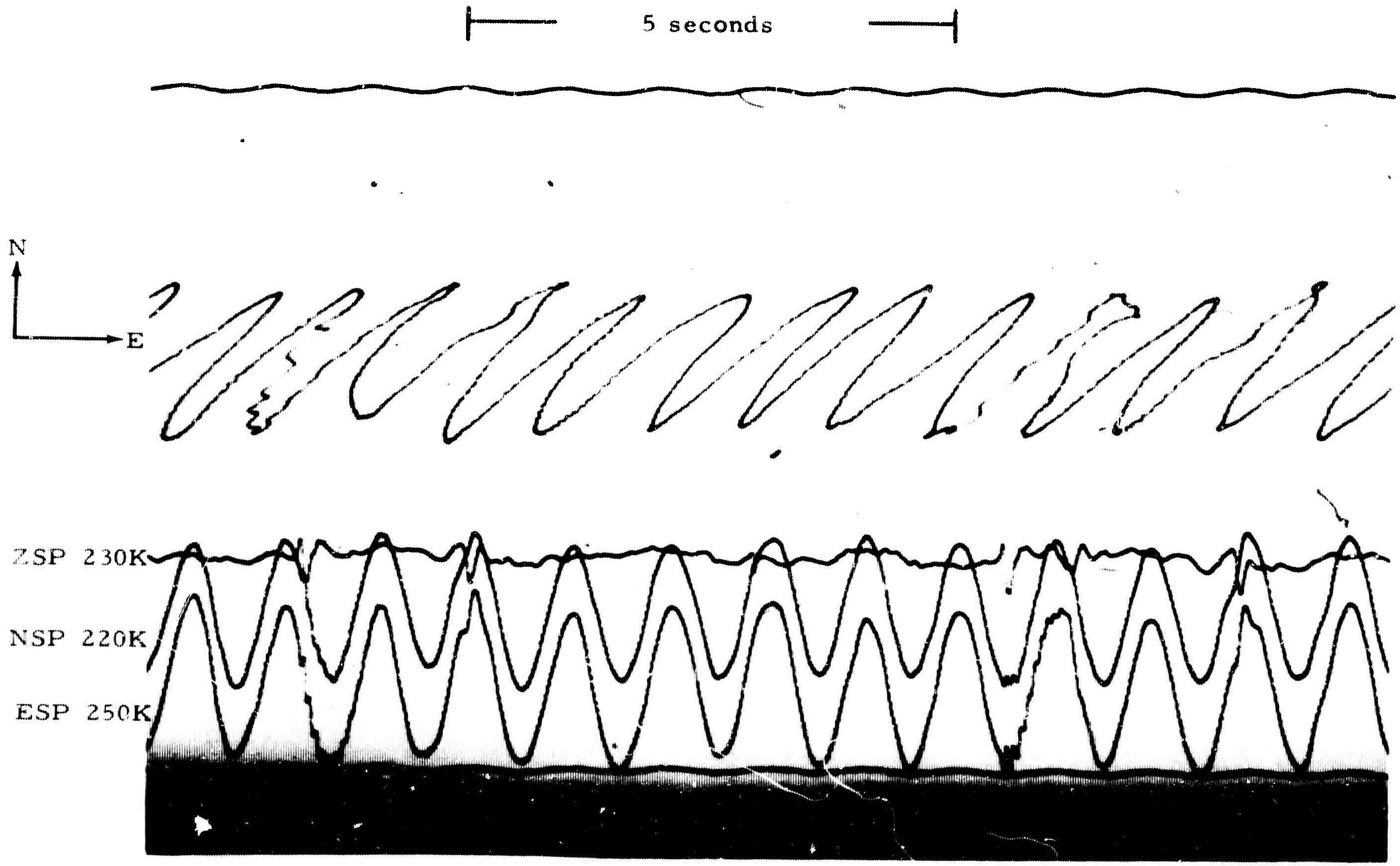


Figure 10. Lissajous display of a 1-Hz calibration recorded on the Model 18621 array display (X10 enlargement of 16-mm film)

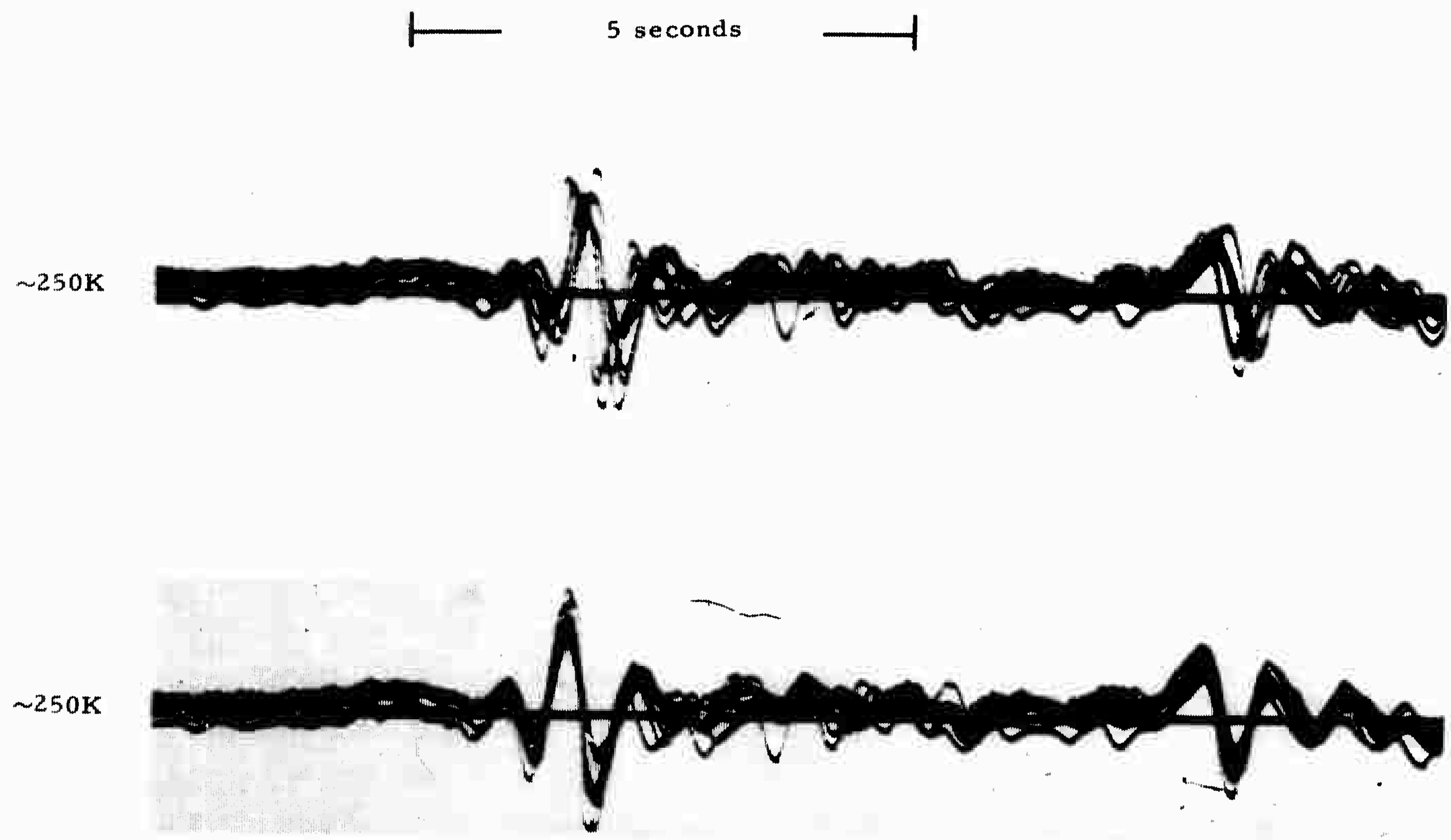


Figure 11. Recording of a teleseismic P wave on the Model 18621 array display with the 10 ZSP seismograph traces superimposed and with the travel times across the array uncompensated (top) and compensated (bottom). Arrival time = 12:48:41.7; epicenter unknown

WMSO
22 Dec 64
Test

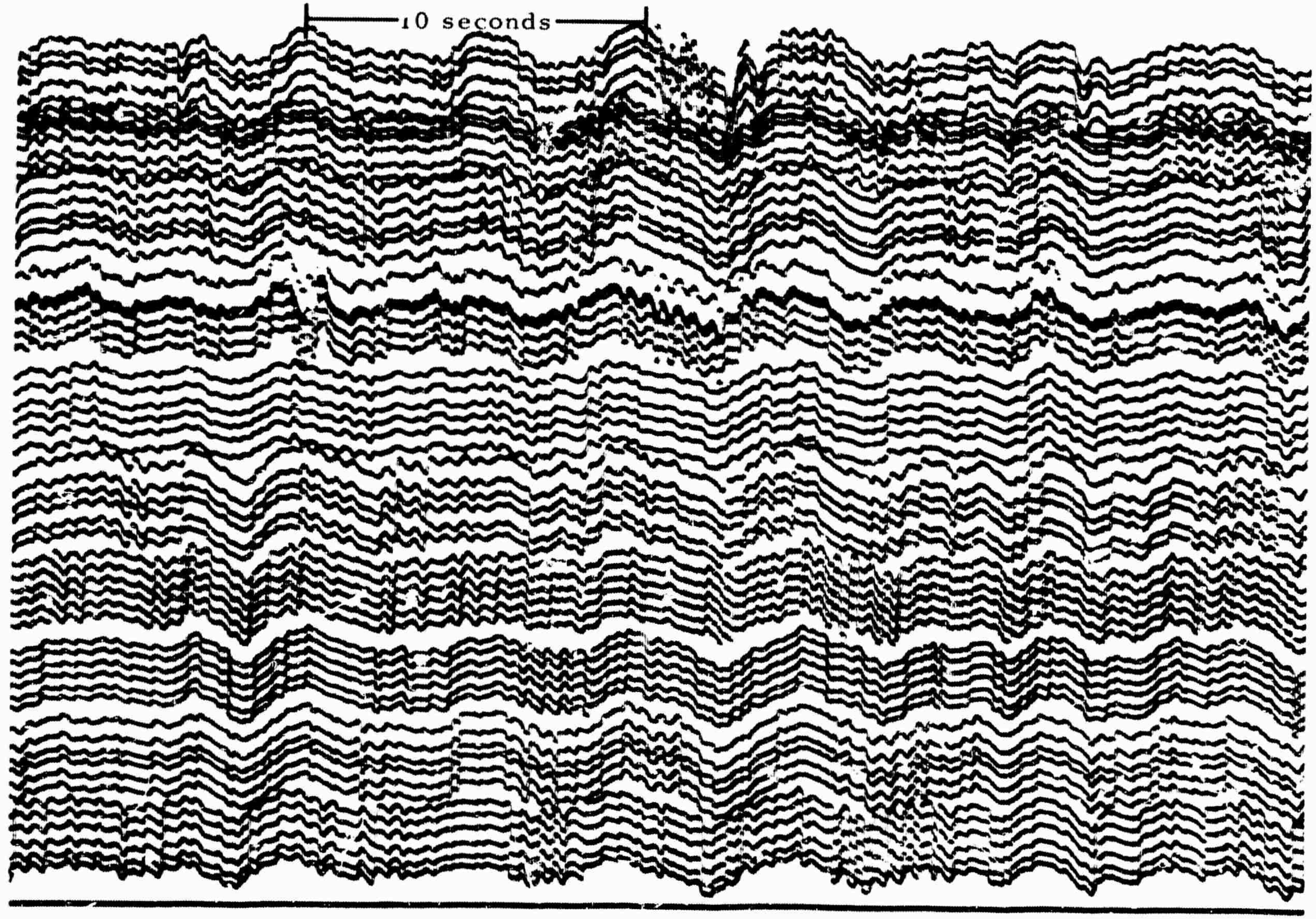


Figure 12. Example of 60-trace recording (each of 10 ZSP seismographs repeated 6 times) on the Model 18621 array processor and Lissajous display. All magnifications $\simeq$500K (X10 enlargement of 16-mm film)

7.6 STRAIN SEISMOGRAPH

Strain work during the reporting period has been directed toward developing a thorough understanding and evaluation of the phase and amplitude performance of the strain seismograph. WMSO personnel, in support of other strain work, completed the measurement of phase and amplitude responses of the short-period, broad-band, and long-period horizontal strain seismographs.

The WMSO vertical strain seismometer, which was damaged in September 1964, was repaired and modified during the first part of this reporting period. Modifications were made in the upper and lower anchor assemblies and in the calibrator assembly. A crosstalk problem between calibrator and signal lines was detected in Garland and eliminated. All repairs and modifications were made under another contract.

A variation in seismometer sensitivity revealed improper setting of the upper and lower anchor assemblies due to internal restrictions. This resulted in false indications of clamping of the anchors, whereas actually, they were either insufficiently clamped or not clamped at all. These internal restrictions were eliminated and proper anchoring was obtained.

The seismometer sensitivity continued to vary after the problems in the anchor assemblies were resolved. Various methods of clamping the seismometer in position were used without improvement. The seismometer was positioned at various depths in the borehole to determine if the borehole was contributing to the problem. No one depth proved to be more satisfactory than another. The variation in sensitivity indicated a possible metal-to-metal contact with the strain member. Inadequate clearance between the strain member and the retaining housing for the O-ring seal was suspected as a source of friction. This O-ring housing was modified to increase the tolerable entry angle of the strain member from 0.5 to 2.0 degrees. This modification failed to resolve the problem. The seismometer was returned to Garland where a careful inspection of its internal construction was conducted. Inspection revealed two major problems:

a. The weak-link bolts in the anchor assemblies were being permanently stretched because of unequal distribution of forces applied by the split ring on the clamp base. The clamp base is being modified to minimize the effect of the unequal forces. Until this modification is completed, stronger weak-link bolts are being utilized and the technique of anchoring has been modified to reduce the stress on the weak-link bolts.

b. Inadequate clearance was discovered in the transducer clamp assembly while in the unclamped position. Adjustments and minor modifications were necessary in the transducer clamp assembly to assure sufficient clearance.

The seismometer was installed in the test hole at Garland and tested at different depths and with different anchoring techniques. The same sensitivity and response were obtained for each condition. The seismometer has been returned to WMSO where performance tests will be resumed.

In general, modifications of the vertical strain seismometer and improved handling techniques developed during the reporting period have greatly reduced the occurrence of malfunctions during installation and removal of the seismometer from the borehole. The seismometer has been set into position approximately 40 times. On three occasions, minor malfunctions necessitated releasing the anchors by breaking the weak-link bolts. However, at no time were any difficulties encountered during removal of the seismometer from the borehole.

The vertical strain Magnetostrictive (MS) Calibrator, Model 15952, was tested at WMSO for response performance. The calibrator was installed on the fixed end of the north horizontal strain seismometer. Calibrator response tests were performed and compared with the horizontal strain electromagnetic calibrator. Conclusions drawn from these tests follow:

a. The amplitude response of the magnetostrictive calibrator compares favorably with the electromagnetic calibrator for a calibration current of 4.0 mA and a bias voltage of 12 Vdc.

b. The sensitivity of the MS calibrator is lower by a factor of 4 than the value previously obtained by measurements in the laboratory. The revised sensitivity in the band of interest is 5 mμ at a calibration current of 4 mA.

c. The MS calibrator does not appear to be load sensitive for loads up to 120 pounds.

8. RESEARCH INVESTIGATIONS

8.1 DETECTION CAPABILITY STUDY

Analysis of the seventy-eight 16-mm synthesized seismograms selected for the detection capability study was completed during this reporting period.

A FORTRAN program designed to tabulate the probability of detection for each noise type as a function of signal trace amplitude, ground amplitude, and ground velocity was written and later revised to accomplish automatically the grouping of signal-level class intervals in which the signal amplitudes fall within 1 dB of each other. At present, analysis data for the detection study has been processed by the computer and results are being plotted.

Preliminary data from the detection capability study for WMSO were sent to the Project Officer during March. A copy of the computer program written in FORTRAN language was furnished to SDL at the request of the Project Officer.

8.2 SPECTRAL ANALYSIS OF SHORT-PERIOD DATA

In order to determine the recording level of short-period microseismic noise relative to line noise, PTA noise, and tape recorder noise, a recording was made on 25 November 1964 with each of the following circuit conditions imposed on Z6 (Channel No. 8 on Tape Recorder No. 1):

a. The data line was dummy loaded (110 Ω resistor in place of seismometer).

b. The PTA input was disconnected from the line and dummy loaded.

c. The tape recorder input was disconnected and dummy loaded.

Three-minute recordings of each of these three conditions, and a 3-minute recording of normal microseismic noise were digitized at SDL and used in the computation of the power spectra. Figure 13 is a power density plot of the data obtained in each of the above tests. The relative power density of the microseismic spectrum is at least 20 dB higher than any of the system noise peaks over most of the period range above 0.3 second.

Similar recordings were made of the long-period vertical seismograph but were not analyzed because there was an indication that the LP channel was not functioning normally. A recording made with the data line dummy loaded at the seismometer vault was several times as noisy as the recording of the same channel with the seismometer connected and operating in the usual way. The same result was obtained by blocking the seismometer. There were no indications of excessive noise on the long-period channel when the complete seismograph was operational. This problem has not been resolved but will be more thoroughly investigated in the near future.

8.3 COMPARISON OF JM, BB, AND WORLD-WIDE SEISMOGRAPH SYSTEM

During December, we received a request from the Project Officer to initiate a series of tests to compare earthquake magnitudes determined from the standard JM system, the BB flat-velocity system, and a Benioff vertical seismometer operating into a 0.75-second galvanometer in a PTA (World-Wide SP System).

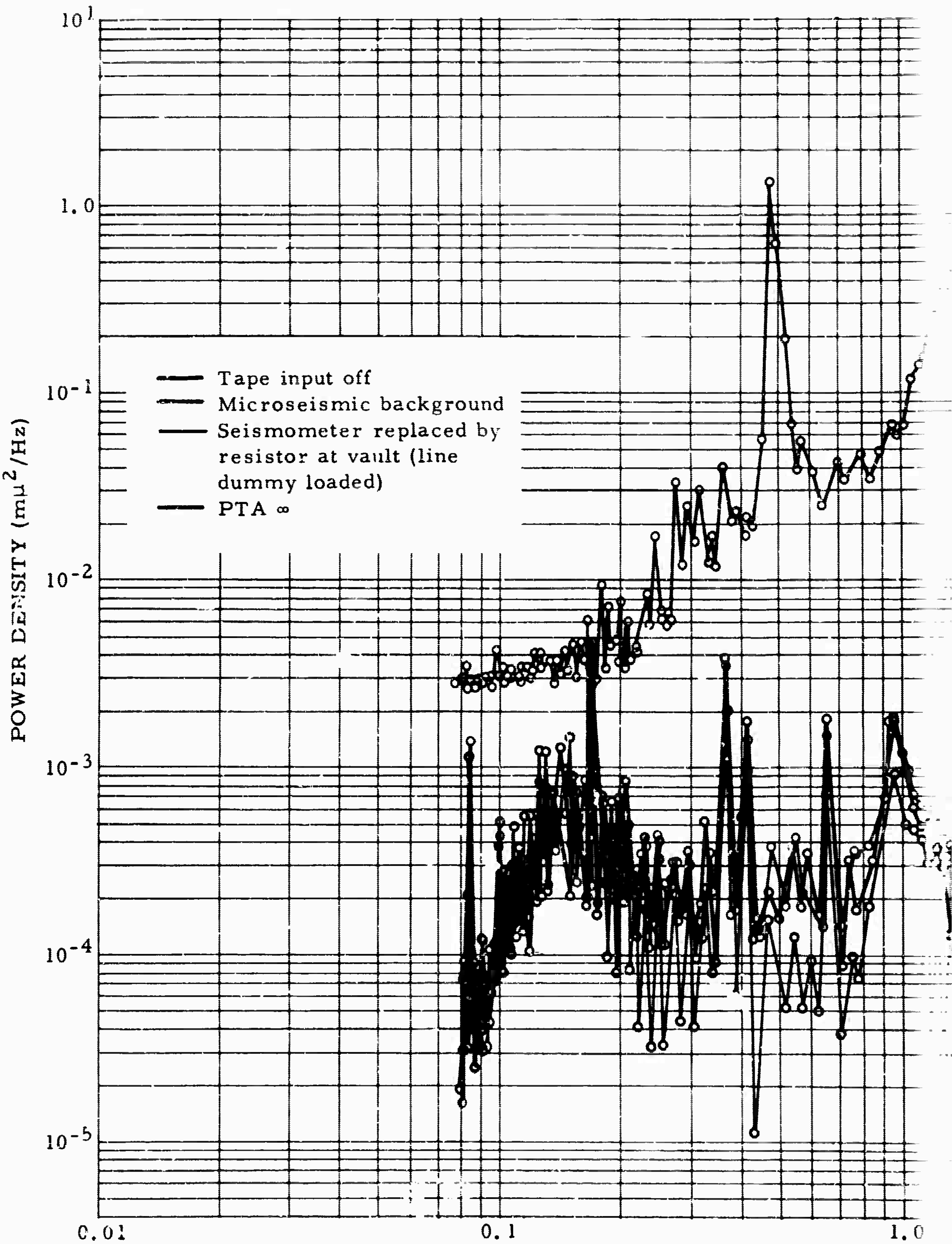
A seismograph with the same frequency-response characteristics as the USC&GS World-Wide Seismographs was set up in vault 6P on 4 January to compare magnitudes measured on the standard JM seismograph (JM6) and the World-Wide Seismograph (WWS). The frequency response of each seismograph is shown in figure 14. The ratio of amplitude-to-period (A/T) of a total of 107 P waves was measured from each seismogram recorded from 5 January through 12 January. The difference between the magnitudes that would be computed from the WWS measurement and the JM6 measurement for each P wave is the difference between the logarithms of the A/T measurements from each seismograph. The magnitude difference was zero for six P waves. World-Wide Seismograph magnitudes were larger than Z6 magnitudes for 53 P waves, with an average difference of 0.06 magnitude unit. Z6 seismograph magnitudes were larger for 48 P waves, with an average difference of 0.07 magnitude unit.

A broad-band flat-velocity seismograph (BBV) was also set up on the same pier as the WWS and Z6 seismographs. The frequency response of the BBV seismograph is shown in figure 15. Of the 107 P waves used for comparison of WWS and Z6 magnitudes, 26 were measurable on the BBV seismograms. The values of A/T measured from BBV seismograms were larger than those measured from Z6 seismograms for all but 2 of the 26 P waves. The average difference between magnitudes computed from measurements of the 26 P waves on BBV and Z6 seismograms is 0.35 magnitude unit.

It was concluded that there is no significant difference between magnitudes calculated from measurements of the WWS seismograms and the Z6 seismograms; however, on the average BBV data yielded magnitudes significantly greater than either WWS or Z6 data. The higher magnitudes calculated from BBV data are probably the result of the fact that the BBV response facilitates more accurate determination of the maximum velocity of a signal than do the responses of either the WWS or Z6 seismographs.

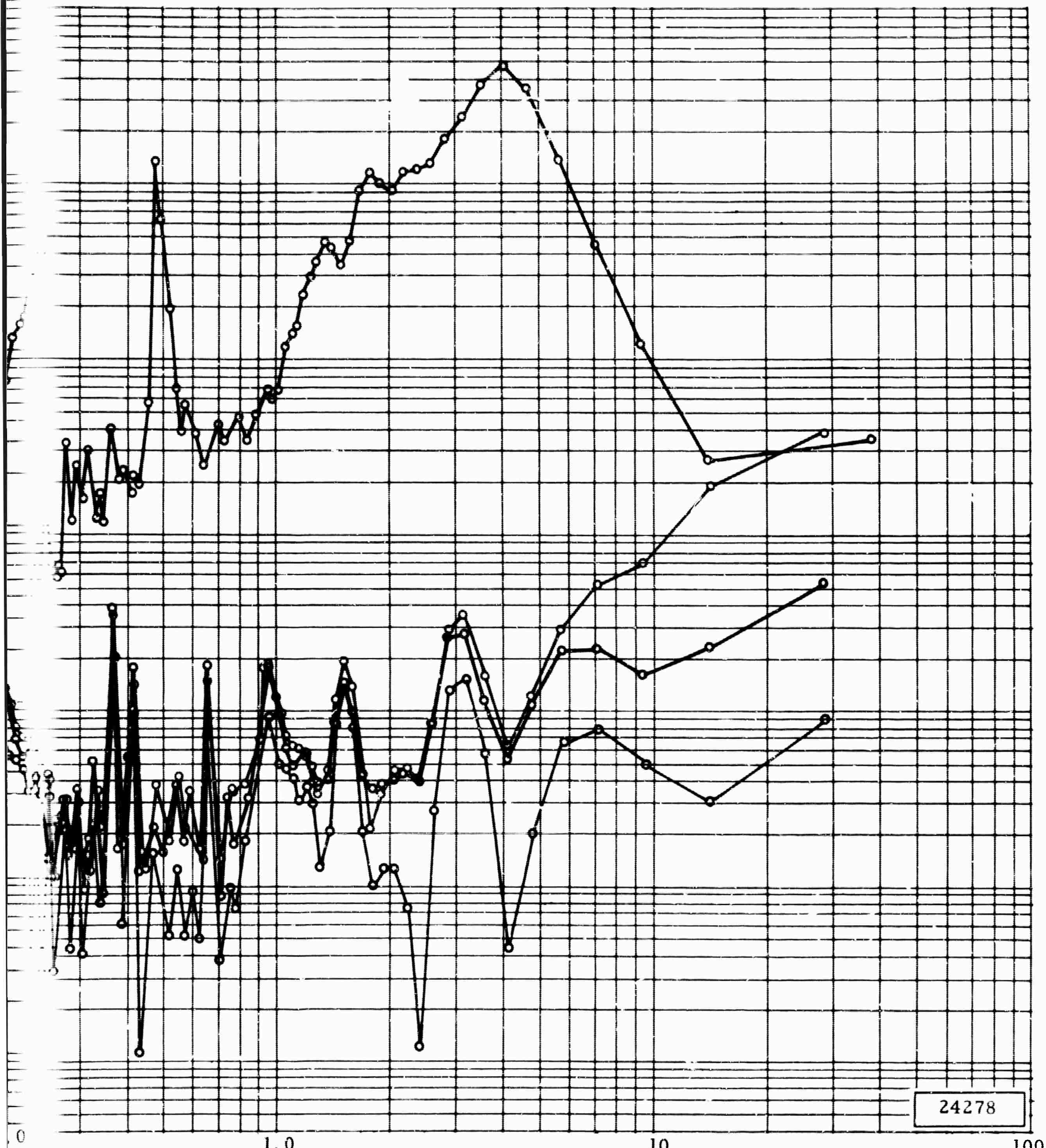
8.4 PRELIMINARY STUDY OF WMSO P-PHASE TRAVEL-TIME RESIDUALS

On 15 February 1964, the Project Officer requested that a study immediately be undertaken to establish the P-phase travel-time residuals at BMSO, CPSO,



A

Figure 13. Power density spectra of micr
of Z6 short-period seismog



B

density spectra of microseismic and system noise
short-period seismograph at WMSO

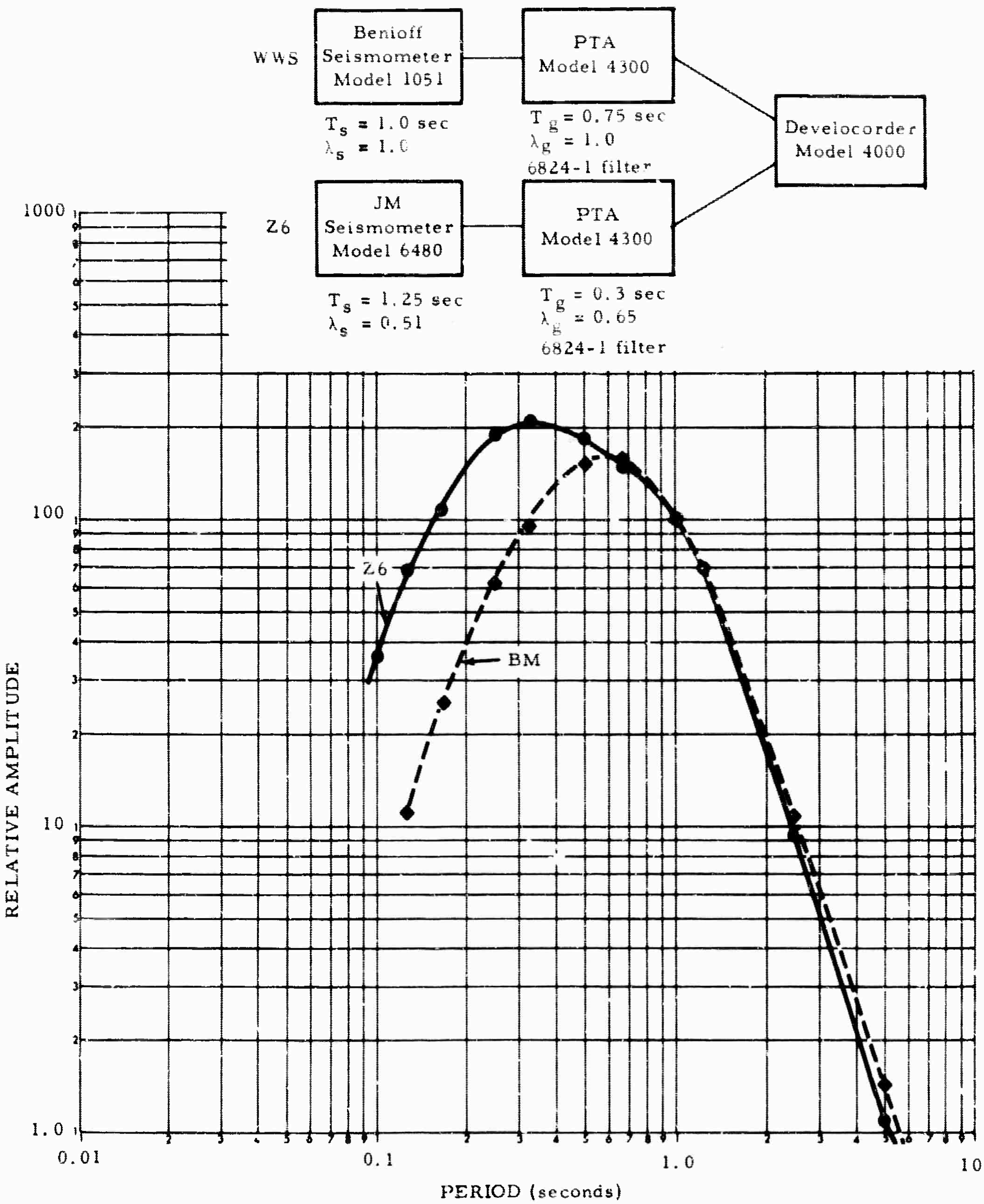


Figure 14. Relative response of the World-Wide Seismograph (WWS) and of the standard short-period JM seismograph (Z6) as a function of period

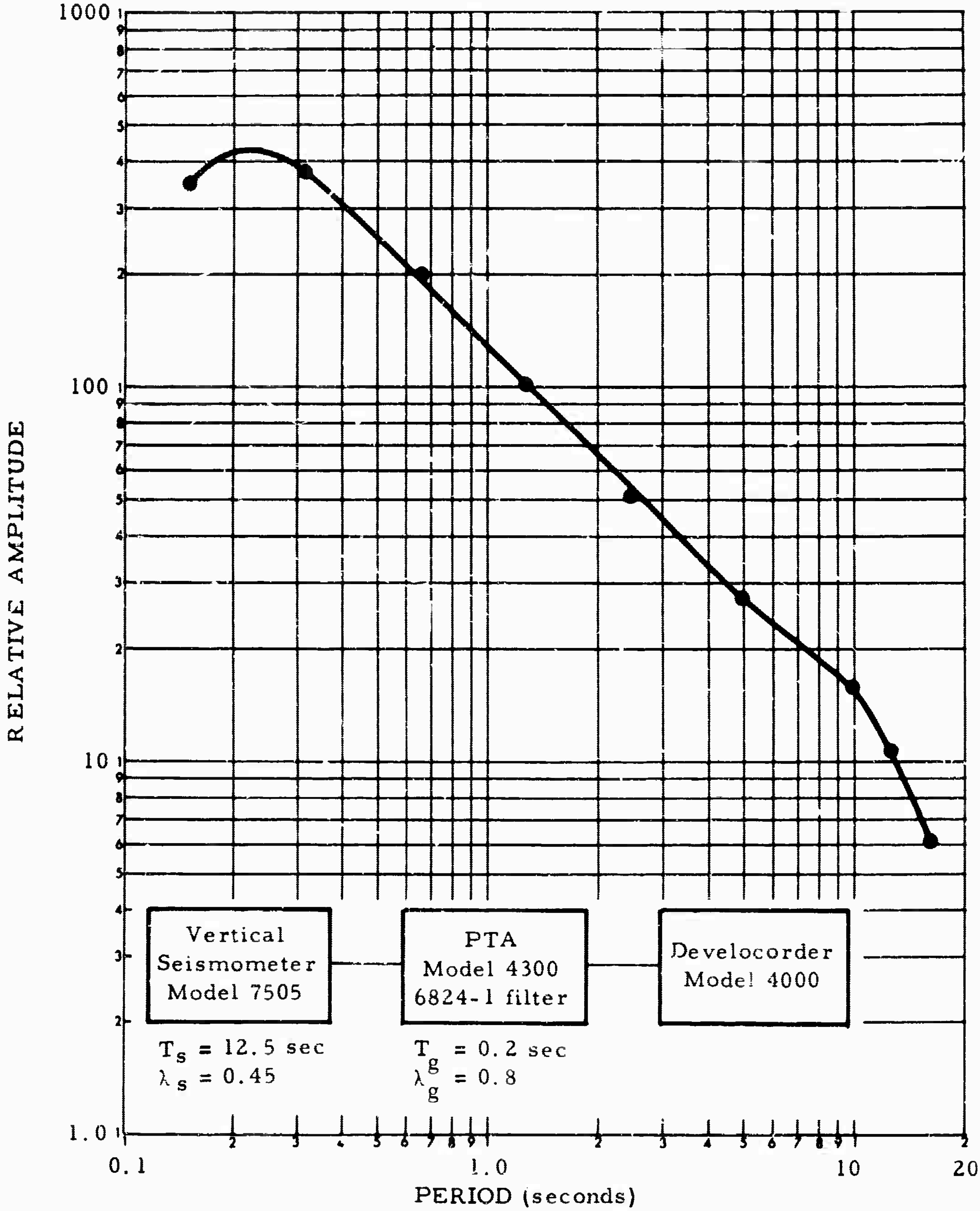


Figure 15. Frequency response of the broad-band flat-velocity seismograph at WMSO

TFSO, UBSO, and WMSO. The 1958 Jeffreys-Bullen (J-B) travel-time tables were used as the basis for comparison of the travel times to each observatory. The origin times as given by the USC&GS PDE cards were used to compute the observed travel times. Residuals were computed by subtracting the J-B travel time from the observed travel time for all events located by the USC&GS and received at an observatory from February 1963 through August 1964.

Figure 16 shows the mean residuals computed from the WMSO data for station magnitudes between 3.0 and 5.0, inclusive; 5.1 and 7.0, inclusive; 3.0 and 7.0, inclusive; and the combined mean residuals computed for all five stations. Further refinement of the data is planned and the computer program has been modified to compute the variance and standard deviations of the data points as well as to define residual window width that will be considered. These refinements are not incorporated in the curves shown in figure 16, because the Project Officer approved a temporary suspension of the study in order to assign top priority to the detection study.

8.5 ROUTINE MICROSEISMIC NOISE DATA

In addition to the analysis of the synthesized seismograms, routine noise measurements are also included as part of the detection capability study. Noise measurements have been completed for September 1963 and January 1964 through March 1965. From these, the frequency distribution of amplitudes was determined and the cumulative distribution plotted. The curves for October 1964 through March 1965 are included as appendix 2 to this report.

Measurements are made of the maximum peak-to-peak amplitude in millimeters at X10 view in the period range 0.4 to 1.4 seconds, with smoothing if appropriate. Samples are taken every eighth hour of the day beginning at 0000Z the first day of each month, 0100Z the second day, 0200Z the third day, 0300Z the fourth day, etc.

Measurements are made at the first 5-minute mark after the hour mark in each case. If seismic signals, wind noise, or any type of cultural noise is present, the measurements are taken at the first 5-minute mark after the designated time free of these types of noise. Measurements are made from the vertical component of the three-component SP system, the summation seismograph recorded on the primary fast-speed Develocorder, and the filtered summation seismograph. In addition, measurements are being duplicated on the ultra high-gain SP vertical and unfiltered summation seismographs in an effort to determine if the additional gain will provide a higher degree of resolution of the background noise.

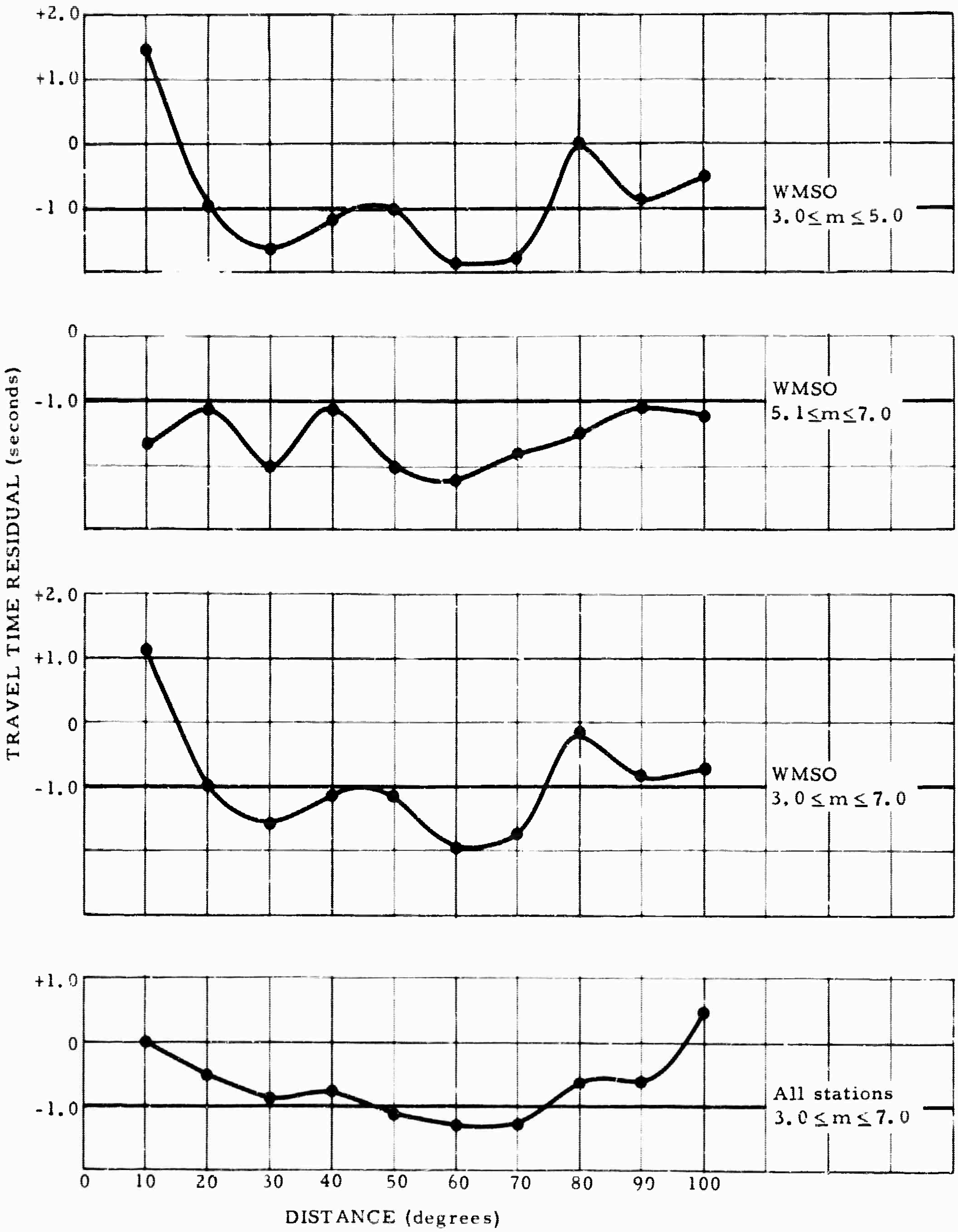


Figure 16. Mean travel time residuals as a function of station-to-epicenter distance (observed travel time minus J-B travel time)

The noise measurement data are punched on IBM cards and a computer used to process the data. From the computer, frequency distributions f noise amplitudes are obtained. These are summed to obtain the cumulative distribution. Two cumulative distributions have been plotted for each of the three seismographs for each month. The probability of occurrence was calculated for trace amplitude normalized to the respective seismograph magnification, and for ground motion.

9. REPORTS AND DOCUMENTS

During this reporting period, several documents were prepared under Project VT/4054 and submitted to AFTAC. A list of these documents with a brief description of each follows:

a. A letter containing recommended revisions for seismograph calibration procedures was submitted to the Project Officer on 26 January 1965.

b. A letter containing preliminary data from the detection capability study was submitted to the Project Officer on 30 January 1965.

c. Letter-type reports Sample Size for Noise Surveys and Precision of Estimation of Seismic Background Noise were submitted to the Project Officer on 23 February 1965. The report discussed the accuracy of noise measurements, the influence of measurement inaccuracies on noise level estimates, and the effects of these inaccuracies on sample size.

d. A letter containing preliminary curves showing the observed mean travel-time residual for P phases recorded at BMSO, CPSO, TFSO, UBSO, and WMSO was submitted 27 February 1965.

e. A summary of recommendations made in TR 64-118 Final Report on the Operation of the Wichita Mountains Seismological Observatory was submitted to the Project Officer on 6 March 1965.

f. A letter-type report, Selection of Microseismic Noise Types for the Detection Capability Study was submitted on 31 March 1965 to the Project Officer. A general discussion of the criteria used in the selection of noise types used in the detection capability study was presented. Examples of each noise type were included.

APPENDIX 1 to TECHNICAL REPORT NO. 65-52

STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/4054

EXHIBIT "A"

STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/4054

15 April 1964

1. Tasks.

a. Operation:

(1) Continue operation of the Wichita Mountains Seismological Observatory (WMSO).

(2) Evaluate the resulting seismic data to determine optimum operating characteristics and make changes in the operating parameters as may be required to provide the most effective observatory possible. Addition and modification of instrumentation are within the scope of work. However, such instrument modifications and additions, data evaluations, and parameter changes are subject to the technical approval of the AFTAC project officer.

(3) Transmit daily seismic reports to the US Coast and Geodetic Survey, Washington DC 20230, using the established report format and the currently available detailed instructions.

(4) Publish a monthly summary of seismological events during this period with distribution and format as approved by the AFTAC project officer.

(5) Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after approval by the AFTAC project officer.

b. Instrument Evaluation: Evaluate the performance characteristics of experimental detection equipment operated under field conditions at WMSO, after approval by the AFTAC project officer. Compare the usefulness and reliability of the new instrumentation with the standard WMSO instrumentation. Of specific interest is the evaluation of the strain seismographs installed at WMSO.

c. Special Investigations: Conduct research investigations as approved or requested by the AFTAC project officer to obtain fundamental information which will lead to improvements in the capability of a seismological observatory. For example, this work might pursue investigation in the following areas of interest: microseismic noise, signal characteristics, data presentation, detection threshold, magnitude determination, and evaluation of identification techniques.

2. Reports.

a. A monthly letter-type management and progress report in 14 copies summarizing work through the 25th of the month shall be dispatched to AFTAC by the end of each month. Specific topics shall include technical status, major accomplishments, problems encountered, future plans, and any action required by AFTAC. Illustrations and

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photographs shall be included as applicable. In addition, the monthly report submitted for the reporting period occurring 6 months prior to the scheduled contract completion date shall contain specific statements concerning recommendations or requirements and justifications for extensions, modifications, or expiration of work and any changes in cost estimates which are anticipated by the Contractor. The heading of each report shall contain the following information:

AFTAC Project No. VELA T/4054
Project Title
ARPA Order No. 104
ARPA Project Code No. 81CO
Name of Contractor
Date of Contract
Amount of Contract
Contract Number
Contract Expiration Date
Project Scientist's or Engineer's Name and Phone Number

b. A list of suggested milestones shall be dispatched to AFTAC in 14 copies not later than 20 July 1964. Milestones are defined as accomplishments which present significant progress when completed. Each milestone shall be briefly described and completion dates shall be estimated. Upon approval of milestone information, copies of SD Form 350 will be furnished for reporting progress against the milestone schedule. The SD Form 350 shall be attached to the monthly report.

c. Special reports of major events shall be forwarded by telephone, telegraph, or separate letter as they occur and shall be included in the following monthly reports. Specific items shall include (but shall not be restricted to) program delays, program breakthroughs, and changes in funding requirements.

d. Special reports, as requested by the AFTAC project officer, may be required upon completion of various portions of the work.

e. An initial technical summary report in 50 copies, covering work performed through 30 November 1964, shall be submitted to AFTAC within 15 days after the close of the reporting period. A semiannual technical summary report in 50 copies, covering work performed from 1 December 1964 through 31 May 1965 shall be submitted to AFTAC within 15 days following the close of the reporting period. A final report covering the entire contract period of 1 July 1964 through 31 October 1965 shall be submitted by 31 December 1965. These reports shall present a precise and factual discussion of the technical findings and accomplishments during the reporting periods. The headings of the reports shall contain the heading information indicated in paragraph 2a.

3. Technical Documents. The Contractor shall be required to furnish the following technical documents:

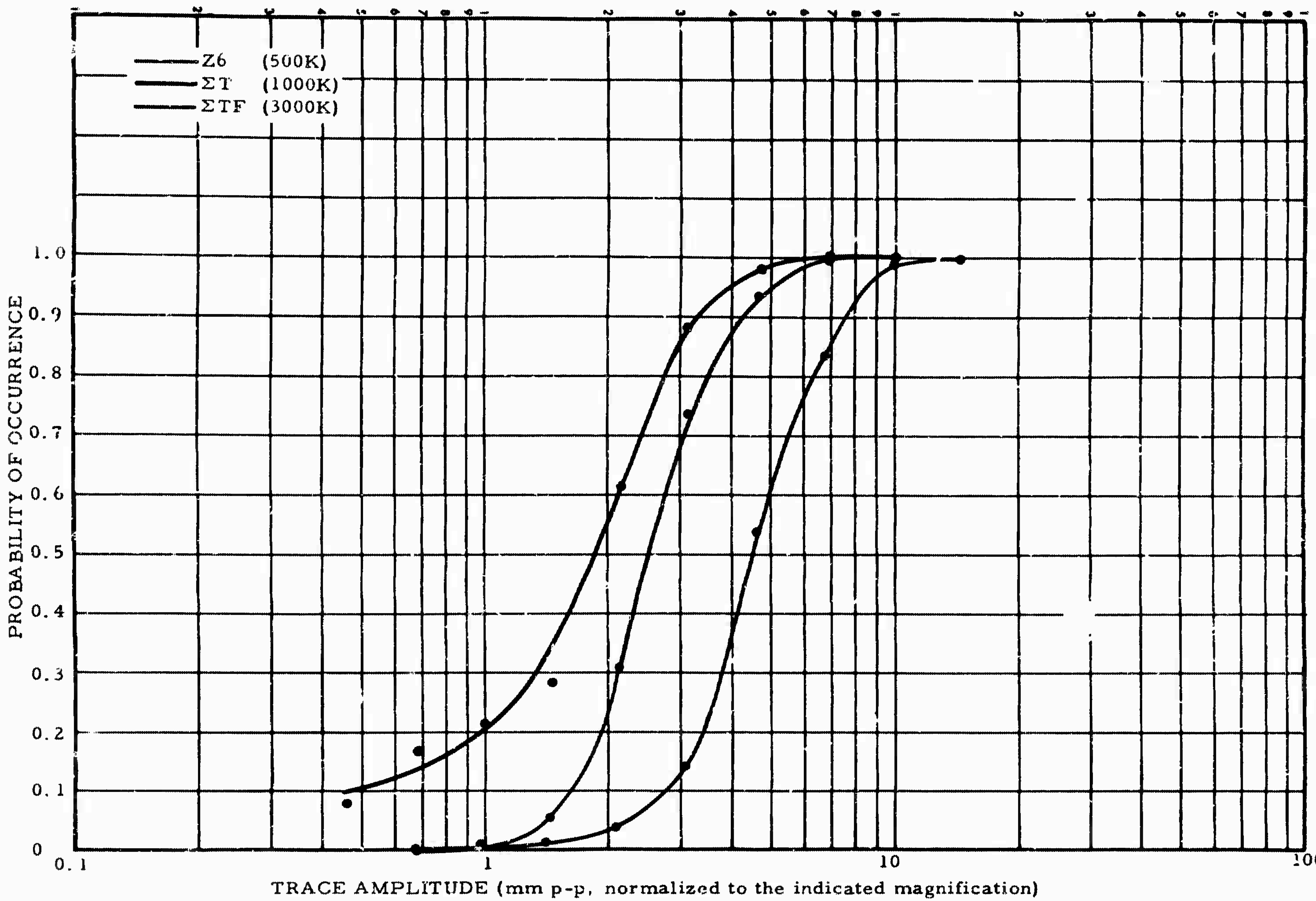
a. All seismograms and operating logs, to include pertinent information concerning time, date, type of instruments, magnifications, etc., as requested by the AFTAC project officer.

b. Technical manuals on the installation and operation of all technical equipment installed during the duration of the contract for this project.

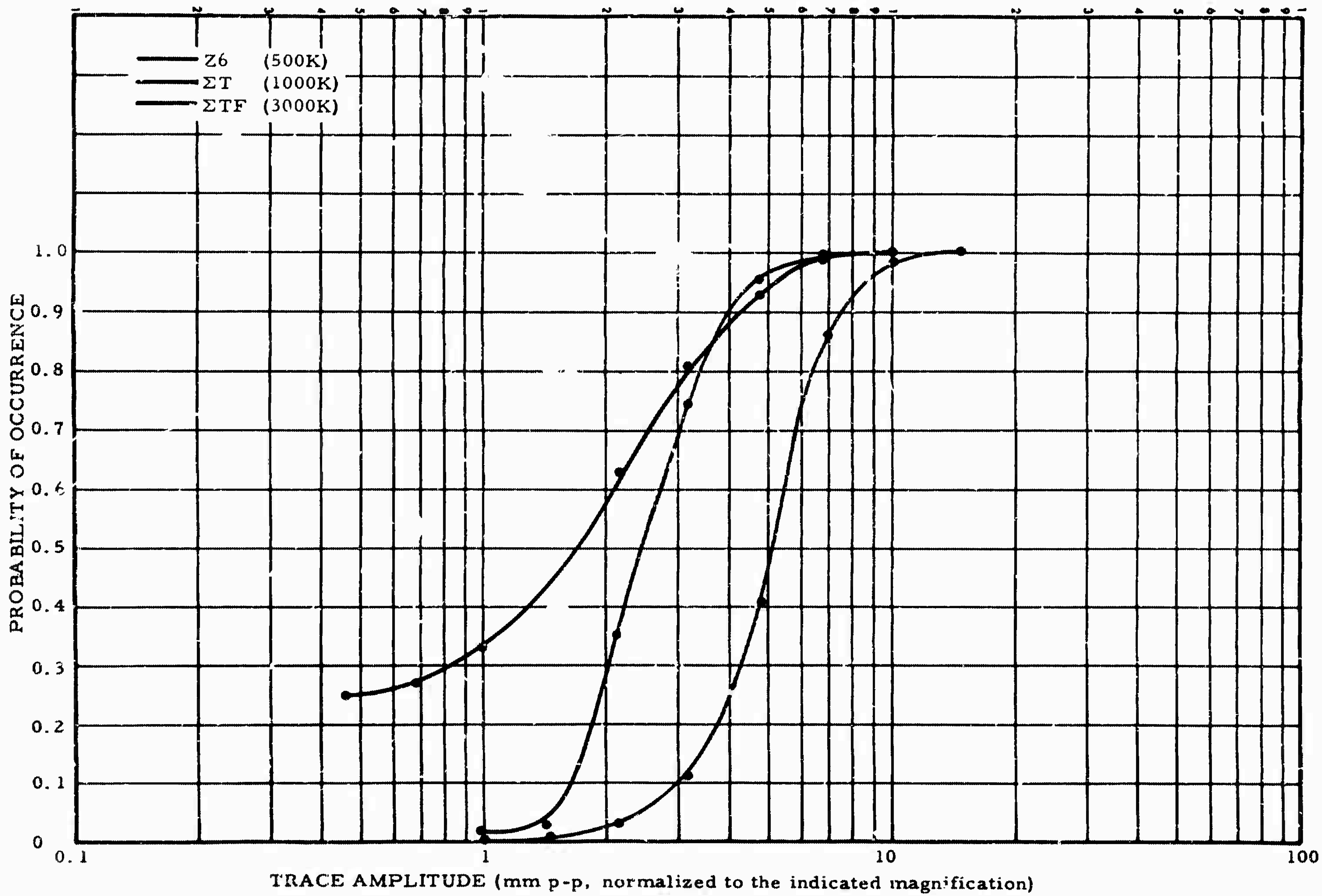
c. Two sets of reproducible engineering drawings and specifications for any changes or modifications in standard operational equipment and instruments, and for any new equipment designed, together with one set of prints of these same drawings.

APPENDIX 2 to TECHNICAL REPORT 65-52

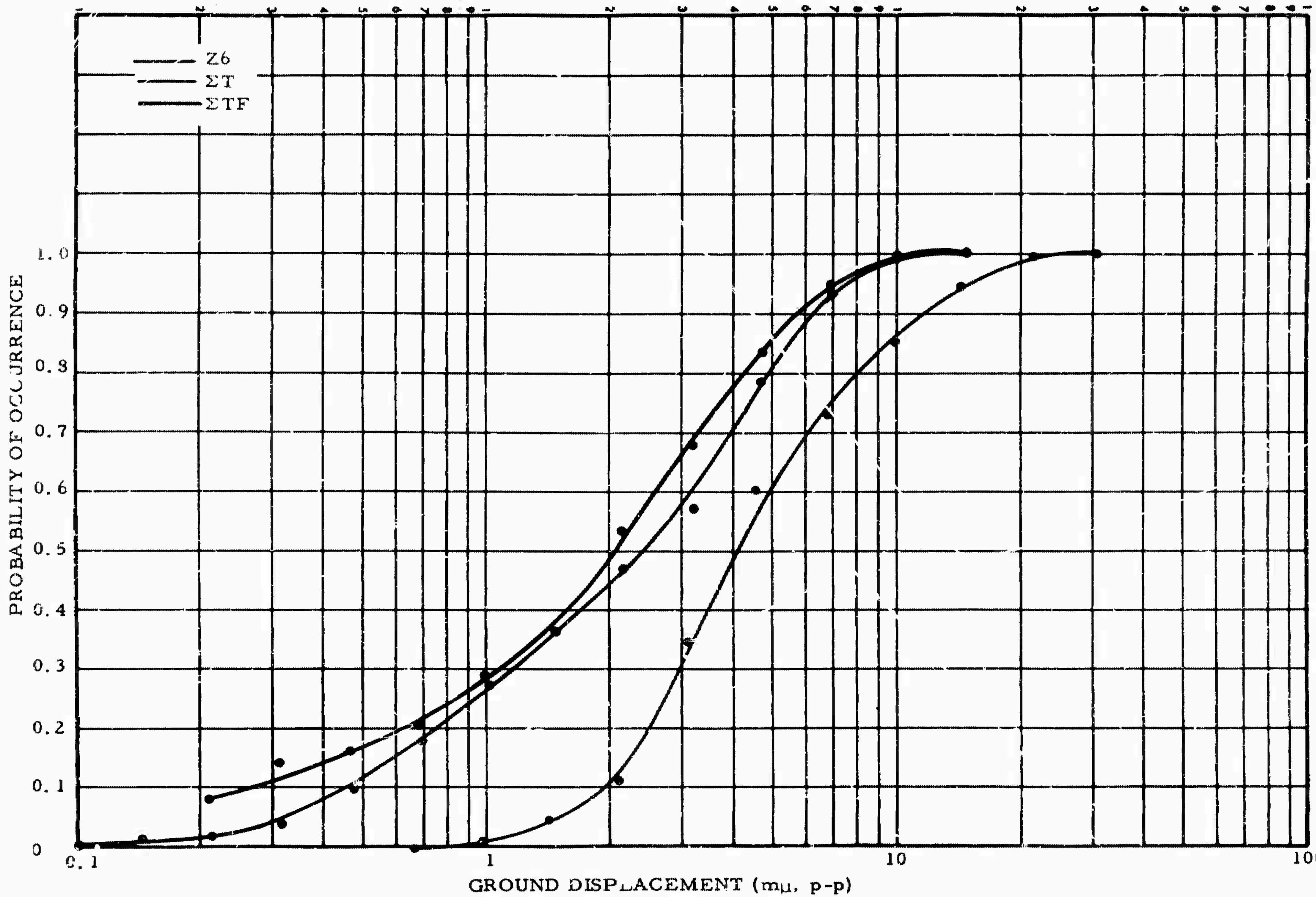
BACKGROUND NOISE AT WMSO, 1 DECEMBER 1964 THROUGH 31 MAY 1965



Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at WMSO during December 1964

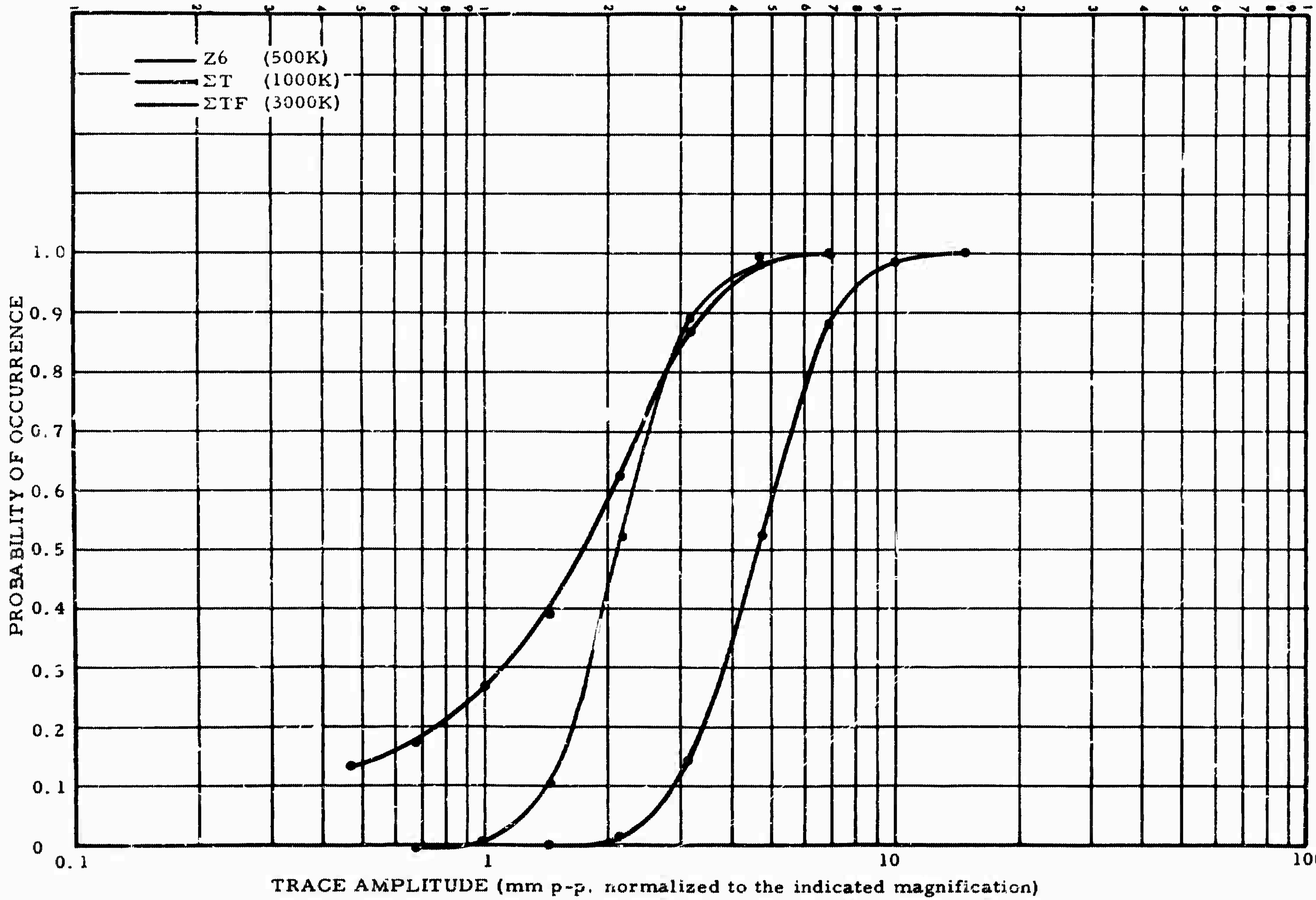


Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at WMSO during January 1965



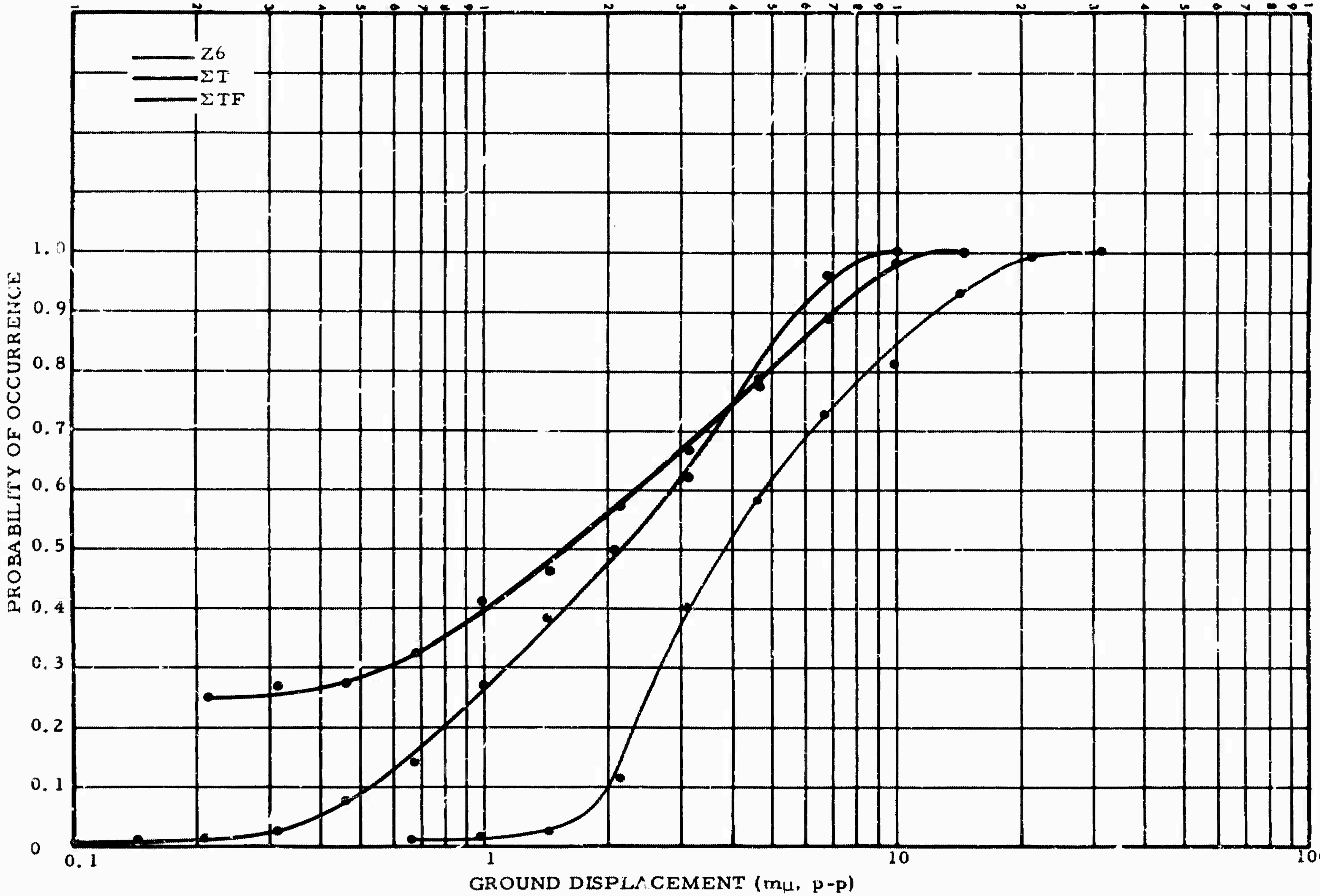
Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at WMSO during December 1964

64 WMO 12-2

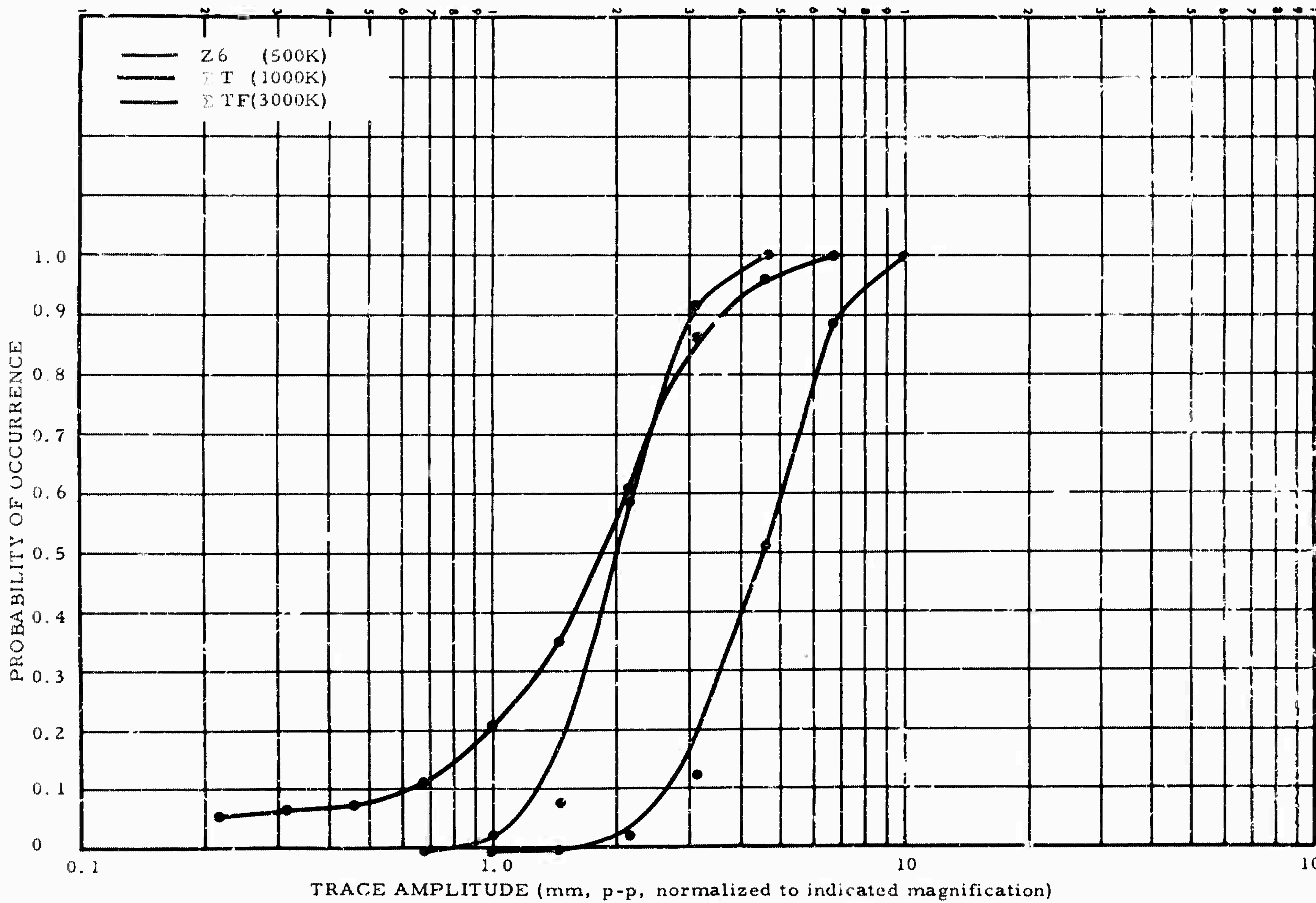


Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at WMSO during February 1965

65 WMO 02-1

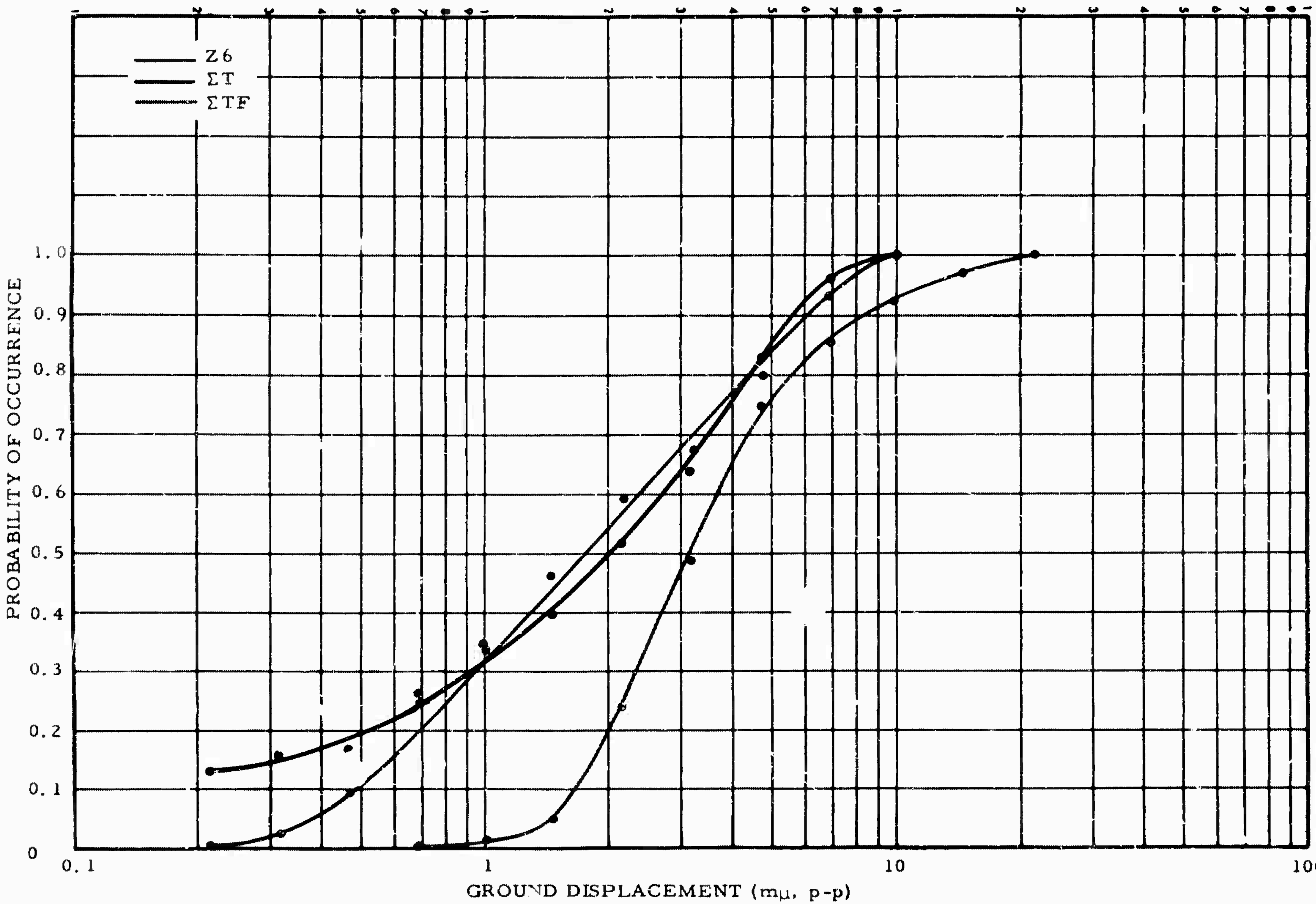


Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at WMSO during January 1965



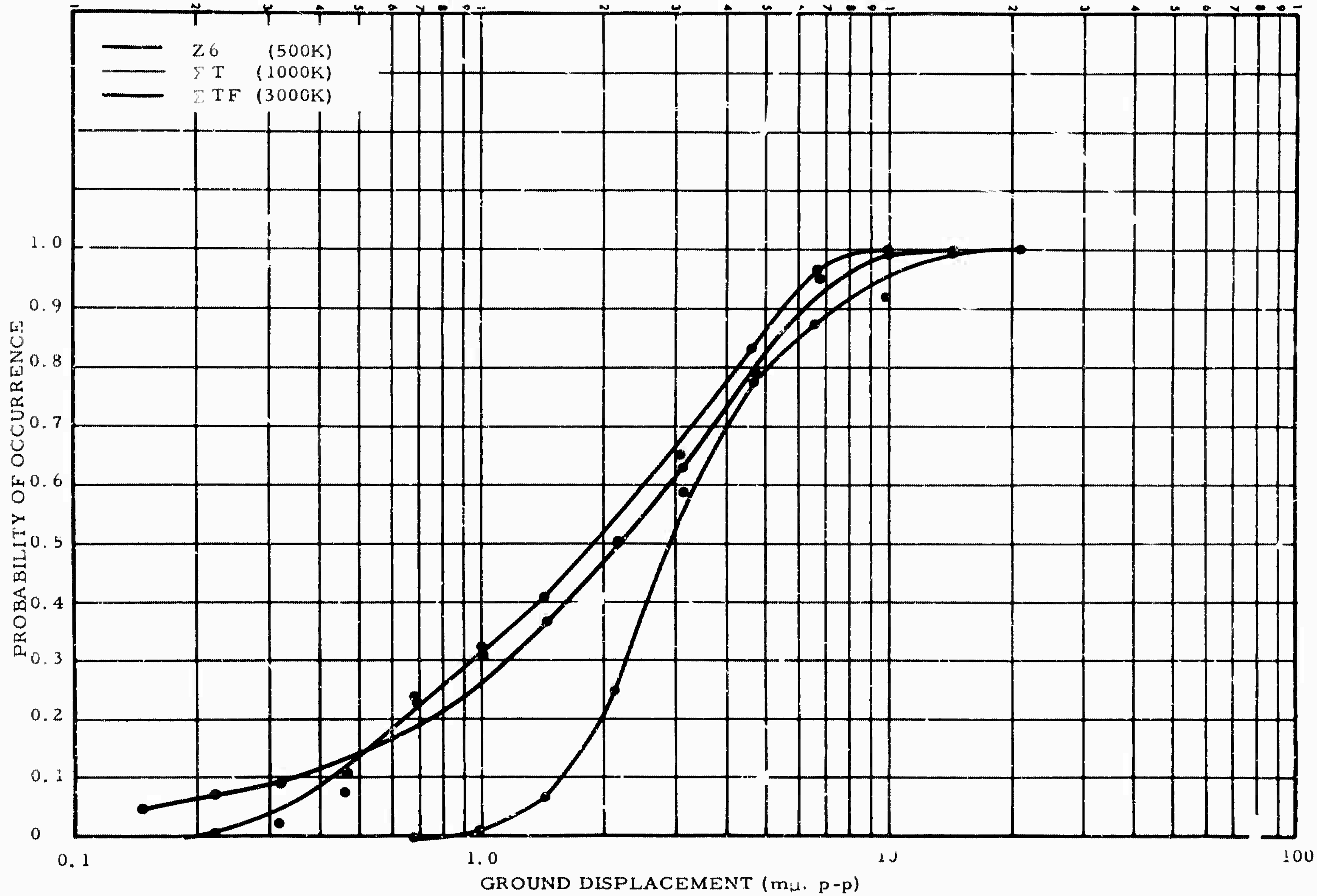
Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at WMSO during March 1965

65 WMO 03-1



Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at WMSO during February 1965

65 WMO 02-2



Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at WMSO during March 1965

65 WMO 03-2

APPENDIX 3 TO TECHNICAL REPORT 65-52

PRELIMINARY SPECIFICATIONS
PTA TEST SET, MODEL 23930

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PRELIMINARY SPECIFICATIONS

PTA TEST SET, MODEL 23930

PURPOSE

The PTA Test Set, Model 23930, is a passive device with two channels for simultaneously monitoring the voltages at the galvanometer stage and the output stage of Phototube Amplifiers, Model 4300 and Model 5240A. It is used to adjust the balance of these stages and to monitor signal voltages.

OPERATING CHARACTERISTICS

Input

Number	2
Voltage	± 15 V max
Impedance	150 kΩ min

Output

Number	2
Type	Voltages are displayed on two self contained meters
Meter scale	35 mm/V @ 0 V input
Sensitivity	1.5 mm/V @ 15 V input
Accuracy	± 10 mV in the range -0.1 to +0.1 V ± 50 mV in the range -0.5 to +0.5 V ± 1.0 V in the range -15 to +15 V

ENVIRONMENTAL

Will meet DSE-4 for sheltered equipment except as below

Temperature range: -40 to +60°C (-40 to 140°F)

PHYSICAL

Height	220 mm (8.5 in.)
Width	250 mm (9.8 in.)
Depth	160 mm (6.1 in.)
Weight	1.0 kg (2.2 lb)

CONNECTORS

Input	Compatible with Model 14486 and Model 4304 power supply

8783